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THE ELEMENTARY SCIENCES
IN
CHAMBERS' EDUCATIONAL COURSE.

CHAMBERS' EDUCATIONAL COURSE.
NUMBER IV.

ELEMENTS OF CHEMISTRY AND ELECTRICITY.

In Two Parts.

PART I.
BY B. D. REID, M. D., F. R. S. E.

PART II.
BY ALEXANDER BAIN,
Inventor of the Electric Clock.

EDITED BY D. M. REESE, M. D., LL. D.

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INTRODUCTION

BY

THE AMERICAN EDITOR.

It being the design of this "Educational Series" to acquaint the young with all the *physical or natural sciences*, by placing in their hands a separate volume devoted to each, it is important that they should be taught to discriminate them from each other, by defining their several natures, objects, and uses.

The general term *Physics*, signifying the science of nature, was formerly understood as including all those departments of human knowledge, which acquaint us with the material universe under every variety of aspect. But with the march of mind, it has been found convenient and useful to classify these numerous departments of knowledge under a few appropriate heads, grouping together those of kindred or similar character which may best be cultivated together.

Silliman

Hence we have, first, *Natural History*, which teaches the *physiognomy or external appearance* of natural objects, whether minerals, vegetables, or animals, with a scientific development of their causes and effects; second, *Natural Philosophy*, or *Physics*, strictly so called, which treats of the *properties* of all bodies in nature, and their action upon each other; and thirdly, *Chemistry*, which instructs us in the *constituent parts or elementary principles* of the multiplied objects of the material universe.

Natural History includes Zoology, Botany, and Geology, together with Animal and Vegetable Physiology and Mineralogy.

Natural Philosophy, now called Physics, comprises matter

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in motion and at rest, including Mechanics, Hydrostatics, Pneumatics, Acoustics, Optics, and Animal Mechanism.

Chemistry, as we have seen, acquaints us with the constitution of all the bodies in nature, and is hence indispensable to the successful study of either the history or philosophy of nature, and for this reason should be first acquired in the order of time. *Organic* chemistry is that department which treats of animal and vegetable life. *Agricultural* teaches the application of the science to the cultivation of the earth. *Pharmaceutical*, its application to the preparation of medicines, &c.

In entering upon this study of chemical science it is important to remember, that as its inquiries chiefly relate to the ultimate elements which compose the constitution of bodies, its operations are for the most part invisible, intangible, and, but for the effects produced, would be altogether inscrutable to the senses. Hence it is strictly an experimental science, and cannot be accurately understood unless the learner, in addition to the lessons derived from teachers and books, will perform experiments for himself. Indeed, a single experiment skilfully performed and carefully observed by the student himself, will impart more real knowledge in the science than can be derived from reading a volume on the subject.

The American Editor.

PREFACE.

The object of this work is to facilitate the introduction of a Course of Chemistry, as an elementary branch of education, in all schools and academies, and to lay a foundation for the young pupil's future progress in Science, and in the more important of its practical applications in the economy of daily life and the useful arts, by awakening his mind to the nature of the material world in which he is placed.

Chemistry occupies a position altogether peculiar, when considered as a branch of general education, from its practical relation to the materials that affect man every moment during the whole period of his existence. No one can study the phenomena of respiration, the nature and varieties of atmosphere to which the human frame is exposed, the theory of combustion, the communication of heat, the production of artificial light, the purification of water, the evolution of poisonous gases, and other deleterious impurities, or any portion of the infinite variety of facts which this science has pointed out or explained, without seeing the important position which it holds with respect to the general economy and management of the means provided by the Author of nature for the existence of man.

Every one, in reality, is more or less a practical chemist, whether he shall study chemistry systematically or not; and it becomes a question, therefore, how far it may be possible to introduce, as a general branch of education, a course of such select illustrations as may enable all to become familiar with the facts connected with this science which influence the wants and comfort of daily life. Such courses would have the advantage of awakening the mind of the young pupil to a more precise understanding of the nature of the material world in which he is placed, and lead him to observe with a philosophic eye many of the phenomena of nature and of art, which, under ordinary circumstances, he altogether overlooks, from the want of a proper key.

They have not been recommended without a proper trial of their practicability. Several years ago, courses were given to upwards of one thousand persons, from different schools and academies, with a view of determining details; and it is submitted, that, were arrangements made for their general introduction, the expenditure of a very moderate sum in each school would be sufficient to provide apparatus for illustrating the more important and essential points in chemistry, connected with the general preservation of health, the use and application of fuel, and the various departments of this science that are continually forced upon the attention in every class of society. It is not contemplated to engage in such preliminary courses with complicated instruments, but to render familiar the use of more simple apparatus, such as there will be no difficulty in experimenting with, after a little practice, while, at the same time, it will be sufficient for all the illustrations required.

In all the schools where such trials have hitherto been made, the pupils entered eagerly into the prescribed exercises. These were evidently, when properly arranged, congenial to their inclinations and adapted to their capacities. One hour a-week, for one session, would be sufficient to lay a good foundation, were no more time granted. And when the illustrations shown by the teacher are conjoined with a system of practical lessons in testing with flat-glass apparatus, the operations in which the pupils engage individually afford a mental exercise of great importance, while they train in early life those that perform them to habits of precise and accurate observation. The union of a certain amount of practice with the theory of the subjects taught, however simple the arrangements by which all the pupils are enabled to join in this department, has been found of great importance in carrying these views into effect. The pupil, as Chaptal has well observed of those who engage in experiments, then sees in his practice the confirmation of all that is told him; he refers all that is said to all that he does; he compares the theory with his own operations, and, in a manner, identifies it with them.

Again, such courses would not only be important in economising the means and increasing the comforts of the poor, but prove equally advantageous to other classes of society. Further, they have become essential for young persons intended for professions where a knowledge of physical science is necessary, as, from the great progress now made in all its branches, without some previous training in elementary schools, it would be as impossible to expect the medical man, the engineer, the architect, the manufacturer, and all who are professionally interested in science, to obtain that amount of information from the usual course of education which is now required, as it would be for any one to maintain a proper rank as a scholar or a mathematician, were he never to enter upon the study of classics or mathematics till he should join a university. Even now, in some professions, it is observed that the period of professional education is not adapted to the present state of science; and if elementary instruction, in some branches at least, be not provided systematically in schools and academies, an extended period must be allotted to it at a future time, which must bear heavily on the means and resources of the advanced student, or college and university courses must be kept at a low level, compared with the ground they would take, were professors not compelled, as they too often are at present, to begin their courses with the most simple and elementary facts, which might be taught more advantageously before the pupils come to them.

Chemistry, accordingly, may be affirmed to have claims upon general attention, which no other branch of physical science presents; and it is also to be considered, from the cognisance which it takes of the composition of matter, as the basis of other branches, which can be associated with it afterwards in each peculiar seminary of education, as local circumstances may determine.

Were the above plan carried more extensively into operation, a great mass of information, in reference to the nature and capability of the materials of which the globe is composed, and of the productions of art, confined among a comparatively small number at present, would, in the course of a very few years, be much more generally diffused throughout the country; and, besides the direct advantages that would be gained in this manner, many other valuable results would be obtained, particularly a more specific knowledge of the nature of the action of external agents upon the human frame; whence additional and more willing assistance might be calculated on in carrying out the details of all public measures for the improvement of health, especially in that class of society whose want of means and of inclination render them most obnoxious to those causes of disease which can be alleviated or removed by care and attention. Nor ought it to be forgotten, that these means would establish, at the same time, opportunities which might enable emigrants to acquire a knowledge of numerous facts, which must be highly valuable to them after they leave their native country, though, perhaps, the establishment of a few local schools for this purpose, in the principal ports from which they embark, would also be desirable.

The leading outlines of the plan recommended were fully detailed, a few years ago, in Chambers's Journal,* and I beg to refer to that work for further remarks on the subject.

In using this treatise, the teacher is recommended to show such experiments as his facilities may permit, from the very commencement of his course; and practice will soon enable him to avail himself of numerous adjustments which may not at first occur to him. He ought also to endeavour to arrange a small museum of specimens, commencing with those tests and chemicals mentioned in the last chapter. The frequent use of the chemical abacus described in treating of the particles of matter, will be found materially to assist the general student in ascertaining the precise nature of numerous chemical operations, more especially when he has not the advantage of frequently seeing experimental illustrations.

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* See Nos. 226 and 228.

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ELEMENTS OF CHEMISTRY.

PART I.

CHAPTER I.

INTRODUCTION.—NATURE OF CHEMISTRY.

1. This globe presents a vast variety of materials to view, having many different properties. By these they are distinguished from each other, and adapted for the various purposes they serve in the general economy of nature, and in supplying the wants of man. A knowledge of their properties has been gained by the general experience of mankind, gradually increasing in each successive generation, and also by the discoveries that have so often attended the investigations of men of science who devoted their time to such inquiries.

2. The term Physical Science is usually employed to signify the knowledge of the material world, which has been obtained in the above manner, namely, by observation and by experiment.

3. For the convenience of the student, as well as with the view of providing a clear and systematic classification, it has been customary to consider the facts that have been discovered in various points of view, and to arrange them under different heads or departments. Hence, in particular, have arisen the two great branches of Natural Philosophy and Chemistry, which may be said to constitute

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1. How are the variety of natural objects distinguished?
2. How has a knowledge of these been acquired?
3. What are the two sources of Physical Science?

the basis of every department of physical science, whether it refer to the animal, to the vegetable, or to the mineral kingdom.

4. Natural Philosophy takes cognisance of all those properties of matter in which the form and the stability or motion of matter come into play. The sailing of a boat, the movement of a cannon-ball, the working of a machine, the construction of a building, the alteration in the form of a piece of wood, stone, or marble, as induced by mechanical means, all come within the province of Natural Philosophy. The stability of bodies, motion, its production and direction, and the effect of any impetus produced by one mass of matter acting on or striking another, are always the great objects of consideration.

5. But in Chemistry a very different view is taken. The properties of the minute particles of matter are investigated, and the manner in which the particles of one kind of matter affect the particles of other bodies, when they are intimately mixed with each other.

6. In the department of Natural Philosophy, the materials or masses that may be the object of experiment and observation, present the same general characters before and after they have been observed or made the subject of experiment. The marble that is dug out of the ground is still marble, whether broken into fragments by a rude blow with a hammer, or fashioned into a bust or statue by the chisel of the sculptor, a mechanical change solely having been effected.

7. In chemical action, however, this is not the case; the matters that come into play form more or less a substance having a new appearance, and heat, light, electricity, and magnetism, are often and sometimes all developed in the same experiment. When a piece of coal burns, a chemical action takes place between its particles and those of the air; the coal in a great measure disappears, and the

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4. State the objects of natural science.
5. Give examples.
6. Wherein does Chemistry differ?
7. What example is given to illustrate Natural Philosophy?
8. What agents are developed in chemical action?

air in contact with it acquires new properties, becoming fatal to animal life, and incapable of supporting the combustion or burning of more coal, while heat and light are largely evolved. All this arises from the minute particles of the coal affecting the minute particles of the air, the greater portion of the coal producing matters that are no longer visible, but which are thin and attenuated like the air, however different they may be from it in other respects.

8. If coal be heated without access of air, another series of chemical changes occurs; gas, water, tar, ammonia, and coke, are the result.

9. Again, sugar and salt are dissolved by water, the particles of the fluid uniting with those of the solid; and by mingling various substances, not only are heat, light, and electricity evolved, but solids often become liquid or gaseous, while liquids become solid or gaseous, and gases often pass to a liquid or solid form.

10. The colour, density, lustre, tenacity, and other properties of bodies acting chemically, are frequently so entirely changed, that we cannot with the eye alone recognise in the products the original materials out of which they may have been formed. If sand and soda be heated in a furnace, the particles of the one unite with those of the other, and melt into a transparent glass.

11. A change of properties, then, is the grand and leading character of the operations of Chemistry, not a change of motion, place, or figure, as in Natural Philosophy.

12. But what are the particles of matter? Has any one ever seen them? Can we take any one out from any mass of matter, and examine it by itself? Man has not hitherto been able to answer the former question, nor has

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9. Name the example here cited.
10. What difference occurs when the air is excluded?
11. What of mixing sugar or salt in water?
12. What change of form occurs by mixture?
13. What other changes sometimes result?
14. What results from heating sand and soda together?
15. Contrast the object of Chemistry and Natural Philosophy.

be powers of vision sufficiently acute, nor instruments sufficiently delicate, to enable him to pick out a particle from any mass of matter, and show it by itself. The particles referred to here are not small portions such as would be termed particles in ordinary language, but the minutest portions which it would be possible to obtain were the subdivision of these ordinary particles carried to the greatest extent of which they are susceptible. The progress of Chemistry has pointed out a series of facts connected with the proportions in which bodies combine, which have led universally to a belief in the existence of very small *particles* or *atoms*, by the union of which all masses of matter are composed. And so excessively minute are they supposed to be, that it is considered as impossible for any one to recognise the individual atoms in any mass under observation, as it would be for him to distinguish with the naked eye the various plants, shrubs, flowers, and their leaflets, that may cover the face of a very distant mountain, however distinct its characteristic outline may appear. They are so minute that they are concealed from his imperfect view, though he may see the matter of which they are composed. But were he to acquire a more powerful vision, he would doubtless see every particle in its appropriate place, as palpably as a near inspection would show him the shrubs, the flowers, and the leaflets on the mountain.

13. The atoms, then, which compose masses of matter, may be regarded as the more immediate creation of the Deity, the masses into which they are now united having been produced by the circumstances to which they have been subsequently exposed, and the number and nature of those associated together. They have unquestionably been created with a view to the various purposes to which they have been applied by man; and hence we see, in the most striking point of view, that even in all those inventions which man has made, he has still employed mate-

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16. Of what are masses of matter composed?
17. What other name is given to these?
18. What reflections are suggested?

rials that may be said to have been created for such purposes by the Author of Nature. And, in a chemical point of view, were he able to procure a magnifying glass of sufficient power, he might then be able to trace the progress of individual particles in all their fluctuating changes, recognising them in all their new and varied forms, however different to the naked eye the masses may appear in which they are contained.

14. Again, these atoms or particles are not considered as susceptible of any change, however varied the appearance of a mass of matter may be, owing to the manner in which they are grouped together. They may constitute a thin and invisible gas like the air that we breathe, a dense and ponderous solid, a cloud, or a mobile liquid, according to the mode in which they are associated with each other. What matter is more familiar to us in many different conditions, than that which constitutes ice, water, steam, and the vesicular vapour of which clouds are composed? Neither can they in any way be destroyed by any power that man possesses, or which is known to operate at the surface of the globe. They may appear and disappear before the naked eye, but they still exist as essentially in the thin and invisible gas as in the most ponderous solid. Newton well expressed the opinion that is now prevalent, when he said, that he considered it probable "that the Author of Nature in the beginning formed matter in solid, massy, hard, impenetrable particles, of such sizes and figures as most conduced to the end for which he created them, and that these primitive particles are incomparably harder than any porous solids composed of them, so hard as never to wear away or break in pieces, no ordinary power being able to divide what had been made one in the first creation."

15. These are the particles that produce chemical action, when different kinds unite together or are separated from one another. So small are they, that individu-

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19. Do these atoms exist in every form of matter?
20. In how many forms is water found?
21. Is any one of these particles destructible?

ally they are invisible, and yet so countless are the myriads in which they are gathered together, that they constitute the air, the earth, the ocean, and every thing material that is observed upon the globe. So curiously, also, are they constituted, that they never change their chemical arrangements without the evolution or absorption of heat, light, or electricity. Grand and majestic as the great and most imposing phenomena of nature are, still, whether we look at the thunder-storm, at the hurricane, or at the volcano, it is to the action of countless numbers of the little particles that all must be more immediately attributed.

16. If we turn from the mineral to the vegetable and animal kingdoms, there again we shall find the atoms in incessant action, modified no doubt by vitality or the principle of life, and the peculiar apparatus which, in one point of view, a tree or the body of an animal may be considered, the different structures that are there observed being made from the food partly by chemical action—from materials which were dead, and which, in the progress of time, when death again takes place, by the cessation of vitality, disorganization commences by chemical action, and they return again to their kindred dust. And if in the productions of the animated world a peculiarity of structure be observed, which is never witnessed in the mineral kingdom, this arises from the various particles out of which they are constructed being presented to each other in the living frame, which may be termed, so far as both the chemical and vital relations of the materials composing it come into play, an apparatus constructed by the Deity himself, and in which all the particles must take that peculiar impress and arrangement that depends upon the circumstances in which they meet, just as the texture of any fabric or work of art indicates the peculiar opera-

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22. What powerful agents are evolved when these atoms change their chemical relations?
23. What examples are cited?
24. Are these atoms peculiar to the mineral kingdom?
25. How are they modified in animals and vegetables?
26. When does their disorganization commence?

tion or machinery to which it may have been previously subjected. [There is this difference, however, that chemical action in animals and vegetables is so essentially modified and controlled by the laws of vitality, that it has been distinguished by the name of *vital chemistry.* For the principle of life, while it remains, resists and defeats the action of the ordinary chemical laws, which are operative only upon dead or inorganic matter.]

17. But in what way is chemistry useful, and what purposes does it serve in the ordinary affairs of life? Chemistry teaches the nature and composition of bodies, and many of their most important properties which it is desirable for man to know. It teaches him the nature and qualities of the air that he breathes, of the water which he drinks, of the food upon which he lives, of the apparel with which he is clothed, of the earth upon which he treads, and numerous changes of which they are susceptible, all conducive to his advantage according to his skill in the chemical changes to which they are subject. In short, all bodies with which man is acquainted, being constantly subject to a variety of chemical changes, and in numerous cases prepared entirely by chemical processes for the purposes to which they are applied, no phenomena are more continually forced upon his attention in the works of nature, or in the operations of art, than those which arise from chemical action. But on other occasions they present characters that are valuable from the manner in which they indicate danger, and forewarn him of circumstances that might otherwise render him liable to injury or death; as, when the extinction of a burning candle by the atmosphere of any old well or pit, informs him that it might prove fatal to descend there, the cessation of the chemical changes that accompany the burning of the candle, being proof that the air in the old well or pit is as unfit for respiration as it is for combustion.

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27. By what name is that department of the science called which treats of animal and vegetable life?

28. What does Chemistry teach of bodies?

29. Name some of the familiar subjects in which the science enlightens us.

13. Again, Chemistry is a source of unceasing interest, from the singular nature of the facts which it discloses, and the endless purposes to which they may be applied. It has explained the composition of air, earth, and water, and examined, under the varied action of heat, light and electricity, the powers and properties of different kinds of matter. And how well has man been repaid for his toil and labour in such investigations! Thousands of discoveries have lent their aid in advancing the tide of civilization, and in adding to the comforts of life; the true theory of combustion has been unfolded; and in trying the properties of matter by fire, the nature and energies of steam have been disclosed; while the investigation of various subjects, in some cases not very promising in their first aspect, have afforded the most gratifying results, as in the examination of the chemical qualities of smoke, which has given rise to gas-lighting, and furnished those products that led to the manufacture of India-rubber cloth and other operations, in which numerous establishments are now actively employed.

19. Among the chemical arts that constantly engage the attention of mankind, a glance at a few of the most important will at once show the great extent and importance of a knowledge of Chemistry.

20. Baking, brewing, distilling, and all the operations by which food is prepared from the condition in which it is furnished by nature, are all in general a series of chemical processes. The manufacture of bricks, pottery-ware, porcelain, and glass, of mortar and cements, the extraction of metals from their ores, and the formation of alloys and amalgams, the operations of bleaching, dyeing, and calico-printing, the preparation of soap, soda, acids, alkalies, and of a never-ceasing variety of products usually

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30. What example is given of the utility of this science in preserving life?

31. What evidences of general utility are named?

32. To what inquiries is the discovery of steam-power ascribed?

33. What substance was experimented on, which resulted in the discovery of gas-light?

34. What other manufacture is named as being thus introduced by chemical knowledge?

termed chemicals, in consequence of their generally being prepared by those who have some skill in chemical processes, are all operations that come under this extensive science.

21. Let us look more minutely to the importance of any one of these chemical arts. Take, for example, the manufacture of iron:—"A piece of iron ore, in the condition in which it is usually met with in this country, presents nothing but a dark stony-looking mass, uninteresting to any one acquainted with its composition, and ignorant of the power which Chemistry possesses over it. Subject it, however, to the operation of the blast furnace, and the metal immediately appears; and how varied are the purposes to which it is applied—how many are the forms which it may be made to assume! What are the tools with which the mason, the smith, and carpenter work—those who contribute so large a share to the comforts of life in every civilized community? Iron is the element of which they are composed; iron is the element by which they are made. What are the instruments with which the miner penetrates into the bowels of the earth, and acquires dominion over the mineral kingdom? Are not the pick, the axe, and the spade, made of the same material? In the hands of the agriculturist, it forms the plough and the pruning-hook. With the soldier, it passes into the sword, the gun, the pistol, and numerous other instruments of attack and defence. But let us turn again, and we see it in the cutting-knife of the surgeon, mitigating, by its severe yet wholesome operation, the most dreadful maladies to which humanity is subject. Look at it in the steamboat, contending with wind and tide on the ocean; and in the steam-coach, see how it outstrips the fleetest horses! Look to it in the little needle employed in the finest and most delicate embroidery. Look again, and you see it in the beam of the mighty steam-engine, wielding with its

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35. Name some of the arts, which consist of a series of chemical processes?

36. What chemical art is selected for amplification?

37. Name some of the striking examples of the value of iron, and the uses to which it is applied.

single arm a power superior to the united energies of a thousand men. It forms the bolts that bind together the timbers of every vessel that leaves our shores, each in itself a monument of art, a moving citadel; it forms the magnet that guides their path across the trackless ocean, and the anchor that stays them in the storm. In many ships as they are now constructed, this metal may often be observed replacing even the very timbers that are usually employed. [So that vessels of the largest class now traverse the ocean, which are built entirely of iron.] It forms the ink, and now even the very pen, with which we write. In the printing-press it is still more conspicuous, assisting in that great engine for the diffusion of knowledge. And in the watch-spring, it enables us to count the fleeting moments as they pass away. But volumes would be required to tell all the purposes to which it is applied; and still we cannot forget that it can neither be extracted from the ore, nor applied to any of these objects, unless by the powerful aid of chemical action. And Chemistry abounds with facts such as these.

22. "It has indeed thrown a new light on the phenomena of nature, and explained a thousand mysterious operations, of which formerly we were completely ignorant. Chemistry, also, in unveiling the natural operations that are carried on at the surface of the globe, has made us acquainted with numberless agencies, whose continued action is essentially necessary to preserve the order of nature, and affords us a new display of that stupendous power and wisdom that commanded order out of chaos, and imposed upon every atom powers as necessary to the present state of nature, as the regularity of those movements that keep the mightiest orbs balanced in their spheres, so that amidst incessant changes, no jarring element is allowed to disturb the harmony of the whole. There is no science which is more admirably adapted to form a pleasing and an interesting pursuit. He who is acquainted with Chemistry has a new key to explain the works of nature; nor can he

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38. Does chemistry explain mysteries in nature?
39. What moral reflections are suggested?

walk abroad without finding in all her operations, and in all the products of the material world, a new source of important and interesting instruction."*

CHAPTER II.

GENERAL OBSERVATIONS ON MATTER AND CHEMICAL ACTION.

23. MATTER is observed at the surface of the globe in four very different forms, namely, in the solid, liquid, gaseous, and vesicular form. Earth, water, air, and clouds, present familiar examples of these conditions.

24. SOLIDS are particularly distinguished by the comparative rigidity of their texture, opposing considerable resistance to any attempt that may be made to reduce them into smaller parts. They are in general the heaviest bodies observed at the surface of the globe.

25. LIQUIDS are distinguished by the extreme mobility of their particles, these moving upon each other, changing their relative position, and producing currents from numerous causes that have no such effect on solids.

26. GASES are thin and attenuated compared with solids and liquids, and are still more mobile than water and other liquids. Vapours constitute a variety of gases, differing from them, as steam differs from atmospheric air, in so far as the one is condensed by cold into water, while the other is not affected in this manner by any degree of cold to which it has hitherto been exposed.

27 VESICULAR VAPOURS present matter in a peculiar condition, into which many vapours pass, under circum-

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* From the Study of Chemistry, by Dr. Reid. See Chambers's Journal.

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40. In what variety of forms is matter observed upon the surface of the globe?
41. Give examples of each.
42. Define each of these forms.
43. What single substance appears in them all?

stances which have not hitherto been satisfactorily explained. Clouds present a familiar variety of vesicular vapour.

28. A number of substances are capable of appearing in all these forms; as water, which can be frozen into ice, converted into steam by boiling, or made to present the appearance of vesicular vapour when the steam is allowed to come in contact with the air. Other bodies cannot be made to present such changes; but where the texture is not altered or destroyed by the application of heat or cold, it is considered that it would be possible to cause similar changes in all bodies by the action of more intense heat and cold than can be at present produced.

29. In a chemical point of view, all bodies, whether in the solid, liquid, gaseous, or vesicular form, are regarded more especially as being *simple* or *compound.*

30. Any matter from which nothing different from itself can be obtained is considered simple, and termed an *element:* thus sulphur is called an element, because, do what we may with it, nothing different from sulphur can be procured from it. *Compounds* consist of different kinds of matter which may be separated from each other, as salt-water, from which the water may be separated by boiling, when the salt is left.

31. All masses of matter are composed of small particles (see par. 12, &c.), and these being considered indivisible, are termed *atoms.* They must be exceedingly small, though their exact size is unknown, as a single grain can be divided into many millions of parts. To illustrate this:—Put one grain of sulphate of iron, which contains only about a fifth part of iron, into fifty ounces of water, and add a few drops of a solution of the ferrocyanate of potassa. Every portion of the water is coloured by the ferrocyanic acid, one of the ingredients in the

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44. Upon what do these changes of form depend?
45. How are all bodies chemically classed?
46. What is a simple body termed, and how defined?
47. Define a compound body, with an example.
48. How is the minuteness of the atoms of bodies illustrated?

ferrocyanate acting on the iron. A solution of the ferrocyanate is prepared at once by pouring upon it in powder ten times its bulk of water.

32. The particles of a mass of any element are similar to each other, and contain only one kind of matter. But the particles of compounds contain two or more dissimilar particles.

33. Masses of matter are *compressible*, *divisible*, and *porous*, but particles are considered *incompressible*, *indivisible* (unless in the case of compounds), and *destitute of porosity*.

34. All particles of matter are subject to the influence of heat, light, electricity, and magnetism, and possess also powers of *attraction* and *repulsion* for matters of the same and also of a different kind, according to the circumstances in which they are placed. The precise cause of these powers of attraction and repulsion is unknown: all that can as yet be stated on this point is the bare fact that matter has been so constituted by the Author of Nature. It is well ascertained, however, that there is a very intimate connection between chemical action and the development of heat, light, electricity, and magnetism, as the particles of matter, in assuming new arrangements in chemical operations, often evolve heat, light, and electricity, while the latter can always be made by various arrangements to develope magnetism in iron. It is also equally known that heat, light, electricity, and magnetism, can in their turn produce chemical changes, when they are brought to act on the particles of matter.

35. By the action of these powers or forces of attraction and repulsion, all changes in the material world are regulated; all bodies, even those that may at one time present a strong and unyielding texture, are subject to decay from the separation of their individual parts, while

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49. What differences are cited between masses and the particles of matter?

50. What powers are ascribed to all the particles of matter?

51. What four agents are named as intimately associated with all chemical changes?

new attractions operate and cause them to assume new forms.

36. In studying the properties of matter, it is important to recollect that these are *primary* and *secondary*.

37. The *primary properties* are observed in all kinds of matter. They include *extension*, *impenetrability*, *inertia*, and *indestructibility*. Matter is obviously extended, and it is also indestructible by any operations to which it can be subjected, in the ordinary course of circumstances observed at the face of the globe. By impenetrability it is intended to signify that no portion of matter can penetrate into the space that is occupied by another at the same moment. The term inertia refers to the fact that matter cannot *of itself* begin to move, or assume a quiescent state after being put in motion.

38. The *secondary properties* of matter constitute those by which one kind of matter is distinguished from another; and they include also the power of attraction, and the relation which matter bears to heat, light, electricity, and magnetism. Of these, the most important is *attraction*, which is termed *gravitation* when it operates between masses of matter.

39. All kinds of matter tend to attract each other, mass to mass, and particle to particle. When a stone is lifted from the ground by the hand, the mechanical effort made by the hand overcomes the force by which the stone is attracted by the earth and retained at its surface. When it is no longer supported by the hand, it falls, or is drawn down to the ground by the attractive power of the earth.

40. Even air is attracted by the earth, and presses upon each square inch of its surface with as much force as a weight of 14·6 lbs.

41. When particles of the same kind of matter attract each other and unite, a mass having the same properties as these particles is formed, and then the term *cohesion* is

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52. Name the primary properties of matter, and define them.
53. What are its secondary properties?
54. What of attraction between masses.
55. How much is the force of the attraction in the air?

used to express the power of attraction operating between them. But when particles of different kinds of matter unite, the new particles thus formed have properties in which they differ more or less from those substances by whose union they are formed, and the term *chemical attraction* or *affinity* is then employed.

42. No substances can act chemically with each other which are not mixed together in the most intimate manner. Mixture is very different, however, from chemical action; sand and water may be mixed intimately together without producing any chemical change, but if salt and water be mingled together, the salt is dissolved by the water, combining with it and disappearing, while the water acquires a salt taste.

43. By heat, light, and electricity, many kinds of chemical action may be effected, which do not take place by mere mixture.

44. All *chemical action* consists in combination or decomposition. *Combination* signifies the union of particles of different kinds of matter, as when sugar unites with water. By *decomposition* is understood the separation of particles of different kinds of matter which had previously been united, as the separation of salt and water from sea-water.

45. Solution.—Suspend a piece of aqueous sulphate of copper (common blue vitriol), in thin gauze in a beer-glass or glass jar full of water. The particles of both combine, and form a stream of blue fluid, which descends from the points where they are in contact. The solid is said to be *dissolved*. The compound is called a *solution* of the solid.

46. Put a piece of an iron hoop, a few inches in length, into any glass vessel, cover it with water, and pour upon it aqueous sulphuric acid, equal to 1-6th of the bulk of

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56. When particles of the *same* kind of matter are united, what is the attraction called?

57. And what, if different kinds are united, forming new compounds, unlike what they were before?

58. Illustrate the difference between mixture and chemical action.

water employed; so powerful is the chemical action exerted, that the particles of acid and of oxygen separate all the particles of iron from each other, and combine with them; the hydrogen, the other element of the water, is disengaged in the gaseous form.

47. Precipitation.—Fill a beer-glass full of water, and dissolve in it ten or twelve grains of bichromate of potassa (a salt composed of chromic acid and potassa), adding it in powder. Dissolve as much acetate of lead (common sugar of lead), consisting of acetic acid and oxide of lead, in another similar glass with water, filtering the solution obtained, if it be turbid. On mixing the solutions, the chromic acid and oxide of lead combine, and produce a solid compound which falls down, and is said to be *precipitated*; the acetic acid and potassa unite, and remain in solution.

48. Effervescence.—Put a table-spoonful of carbonate of soda (common soda) into a large beer-glass, cover it with water, and pour upon it aqueous sulphuric acid (oil of vitriol) as long as gas escapes. The chemical action consists in the union of the particles of the sulphuric acid and the particles of the soda, and the separation of the carbonic acid, the other ingredient in the carbonate of soda; it is expelled with *effervescence;* this term is applied whenever gas escapes rapidly from any liquid.

[Efflorescence.—Expose crystals of Epsom salts to the air, and they will soon be covered with a dry powder, by losing the water of crystallization, and be no longer transparent or bright upon the surface. Such salts as undergo this change are said to *effloresce.*

Deliquescence.—When crystals of any salt become fluid on exposure to the air, by attracting the moisture from the atmosphere, they are said to *deliquesce.*]

49. Evolution of heat and light.—Mix intimately

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59. What are the two results of chemical action?
60 Define each of them.
61. Give a definition and example of *solution*, *precipitation*, *effervescence*, *deliquescence.*

two or three grains of chlorate of potash with an equal weight of sugar, and touch the mixture with a glass slip, previously dipped in aqueous sulphuric acid. It causes a compound of chlorine and oxygen to escape from the chlorate, which immediately inflames the sugar.

50. NEUTRALIZATION.—This term denotes the complete loss of properties that frequently attends combination. For example: acids render the blue colouring matter of cabbage red, while alkalies turn it to a green; but if the acid be combined with the alkali in certain proportions, the blue is not turned either red or green. It is not affected at all, and the compound is said to be *neutral;* the acid and alkali are said to have *neutralized* one another, each having lost the characteristic property mentioned. To show this experiment, take two glasses containing water tinged with vegetable blue; and after rendering one red by a little sulphuric acid, and the other green by common soda, mix small portions of these liquids in another glass till the blue colour is restored, by the acid in the one combining with the alkali in the other.

51. SATURATION.—This term is employed to denote the largest quantity of one body that can combine with a given weight of another; as when water is said to be *saturated* with salt, or has taken up as large a quantity of any salt as it can dissolve.

52. All bodies do not act chemically with each other; if we shake sand and water in a bottle, whenever the agitation ceases, the sand falls; the water has no chemical action with it. [It is, in such cases, called a mixture, and not a solution.

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62. Give an example of *evolution of heat and light.*
63. Define and illustrate neutralization and saturation.
64. Wherein does a mixture differ from a solution?

CHAPTER III.

ELEMENTS OF WHICH THE GLOBE IS COMPOSED.—CHEMICAL EQUIVALENTS, NOMENCLATURE, SYMBOLS, DIAGRAMS, THE CHEMICAL ABACUS.—GASEOUS ELEMENTS AND COMPOUNDS.

53. All bodies which unite chemically tend to combine in certain fixed or definite proportions. The numbers representing these proportions are called *chemical equivalents.* Thus, one pound of hydrogen combines with eight pounds of oxygen: 1 therefore is the chemical equivalent of hydrogen, and 8 that of oxygen.

54. When bodies unite in more than one proportion, the proportion in each successive compound is represented by a multiple of that in the first compound, as in the following example:

	Nitrogen.		Oxygen.		
Oxide of Nitrogen,	14.2	+	8	=	22.2
Binoxide of Nitrogen,	14.2	+	16	=	30.2
Hyponitrous Acid,	14.2	+	24	=	38.2
Nitrous Acid,	14.2	+	32	=	46.2
Nitric Acid,	14.2	+	40	=	54.2
Atmospheric Air,	28.4	+	8	=	36.4

55. The equivalents of compounds are found by adding the equivalents of their elements; thus, 22.2 is the equivalent of oxide of nitrogen, consisting of 8 oxygen and 14.2 nitrogen.

56. The following list comprises the names of the elements of which the globe is composed, so far as they are known. Before each is placed the symbol by which it is represented, and after it the chemical equivalent or quantity which the symbol indicates. Hydrogen being taken as a standard of comparison, the equivalent number of each element is ascertained by examining that quantity of it which combines with a quantity of hydrogen. Thus,

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65. What terms express the definite proportions in which bodies chemically combine.

66. How are the equivalents of compounds found ?

8 of oxygen combine with 1 of hydrogen; 8, therefore, is the equivalent of oxygen, hydrogen being 1. But if any substance do not combine with hydrogen, then its equivalent is ascertained by finding out in what quantity it combines with the equivalent quantity of any other substance which can unite with hydrogen. For instance, silver does not combine with hydrogen, but 108.3 of silver combine with 8 of oxygen; therefore 108.3 is the equivalent number of silver, for that quantity of silver combines with 8 of oxygen, which, again, unites with 1 of hydrogen.

Symb.	Name.	Equiv.
*H	Hydrogen,	1
*C	Carbon,	6.12
*O	Oxygen	8
*B	Boron,	11
*N	Nitrogen,	14.2
*S	Sulphur,	16.1
*P	Phosphorus,	15.7
*F	Fluorine,	18.7
*Cl	Chlorine,	35.5
*Se	Selenium,	40
*Br	Bromine,	78.4
*I	Iodine,	126.5
Si	Silicum,	22
L	Lithium,	10
Al	Aluminum,	13.7
Mg	Magnesium.	12.7
G	Glucinum,	26.5
Ca	Calcium,	20.5
Na	Sodium,	23.5
Co	Cobalt,	29.5
Ni	Nickel,	29.5
Fe	Iron,	28
Mn	Manganese,	27.7
Cr	Chromium,	28.19
Ir	Iridium,	98.8
Cu	Copper,	31.7?
Ti	Titanium,	23.5
Te	Tellurium,	64.2
Y	Ittrium,	32.25
Z	Zinc,	32.3
As	Arsenic,	37.7
Zr	Zirconium,	33.67
K	Potassium,	39.2
Sr	Strontium,	43.8
Sb	Antimony,	64.6
R	Rhodium,	52.2
Mo	Molybdenum,	47.9
Ce	Cerium,	46
Cd	Cadmium,	55.8
Pd	Palladium,	53.35
Sn	Tin,	58.9
Th	Thorinum,	59.6
Ba	Barium,	68.6
Bi	Bismuth,	71.5
W	Tungsten,	94.8
Pt	Platinum,	98.84
Pb	Lead,	103.7
Ag	Silver,	108.3
Ta	Columbium,	184.8
Hg	Mercury,	203
Au	Gold,	200
U	Uranium,	217.2
Os	Osmium,	99.7
V	Vanadium,	68.5
La	Lantanium,	?

57. The elements are arranged in this list in the order or sequence in which their properties, so far as they are

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67. Name the elements which compose the globe.

enumerated in this treatise, can be most successfully studied.

58. The term *supporter of combustion* is often applied to oxygen, chlorine, iodine, and bromine, because many bodies burn with great facility when brought in contact with them in the gaseous state.

59. Hydrogen, sulphur, phosphorus, carbon, boron, and many metals, are termed *inflammables*, as they are so easily inflamed. These two terms, however, inflammables and supporters of combustion, are used in a less specific sense than formerly, as it has been found that two inflammables often give out heat and light during combination, so that in this case the one would require to be considered a supporter of combustion, and the other an inflammable. All the elements are considered as metals, except those marked with an asterisk. Many are of opinion that silicium ought to be classed with the non-metallic bodies.

60. The names of elements and other chemical terms are generally derived from Greek or Latin words expressive of some leading character of the substance indicated. In some cases they have been used from the most remote antiquity, or have been applied from circumstances altogether accidental.

61. In the systematic nomenclature of modern Chemistry, however defective it still may be, from the difficulty of changing names that have long been familiar, it is always considered desirable that the names of compounds should indicate their *composition*, the *proportion* of the respective *elements*, and their class or order; but in the great majority of cases, these objects are as yet only very imperfectly attained, as exemplified in the terms in daily use.

62. When the same elements, united in the same proportions, but in different modes, produce different compounds, in the same manner as a builder can produce different structures with bricks of the same form, such com-

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68. Name the supporters of combustion.
69. What are the inflammables?
70. What is the merit of the systematic nomenclature?

pounds are termed *isomeric*, from Greek terms signifying the same parts.

63. *Proximate principle* is a term applied to a compound, such as forms a part of a still more complicated compound.

64. Binary, ternary, quaternary compounds, &c., indicate the number of elements or proximate principles in a compound.

65. The names of binary compounds of oxygen, chlorine, iodine, bromine, and fluorine, when not acid, terminate in *ide*, as oxide of lead, chloride of mercury.

66. In binary compounds of other bodies, not acid, the name terminates in *uret*, as sulphuret of iron, hydruret of carbon.

67. The number of equivalents in the first element or proximate principle named in a compound, is indicated by a Latin numeral; as *bis*, *ter*, *quater* (or *quadro*), in binoxide of mercury, terchloride of gold, quadroxide of chlorine.

68. Greek numerals, *dis*, *tris*, *tetrakis*, indicate the number of equivalents in the second element or proximate principle, as in dinoxide of lead.

69. *Acids* form a numerous class of compounds, which usually have a sour taste, redden the vegetable blues, and lose their characteristic properties when they combine with alkalies, earths, and other substances.

70. *Oxacids* consist of oxygen and other elements.

71. *Hydracids* consist of hydrogen and other elements.

72. A termination in *ic* indicates an acid with much oxygen, as sulphuric acid; a termination in *ous* indicates an acid with less, as sulphurous acid.

73. *Aqueous* is a term now coming into very general use, instead of *hydrate*, to express the presence of water.

74. The term *salt* is applied to numerous compounds,

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71. Define the term isomeric.

72. What is a proximate principle?

73. By what names are the number of these, or elements in a compound, indicated?

74. By what termination is the name of binary compounds of oxygen, when *not* acid, indicated?

consisting of acids and oxides, and has been lately extended to many varieties of compounds differently constituted, and containing neither acids nor oxides. A *salifiable base* is a term applied to alkalies, earths, metallic oxides, and various substances which can form salts by combining with acids and other bodies.

75. The names of salts are composed of the names of their component parts.

76. *ate* is the terminating syllable given in such cases to the name of an acid ending in *ic*, as in sulphate of potassa, composed of sulphuric acid and potassa.

77. *ite* is the terminating syllable when the name of the acid ends in *ous*, as in sulphite of potassa, which consists of sulphurous acid and potassa.

78. A *supersalt* indicates that the properties of the acid predominate, without reference to its composition, as in the supertartrate of potassa.

79. A *subsalt* indicates that the qualities of the base predominate, as in the sub-borate of soda.

80. A *neutral salt* expresses that the compound has none of the characteristic properties either of the acid or base, as in the sulphate of potassa: the term neutral is often omitted.

81. *Haloid salts* are compounds of chlorine, iodine, bromine, or fluorine, with metals.

82. *Oxysalts* consist of two compounds united together, in both of which oxygen forms a component part.

83. *Sulphosalts* are similarly constituted, the oxygen being in them replaced by sulphur.

84. All who wish to become familiar with chemistry ought to study the symbols of the most important elements. The manner of writing symbols is easily understood after a little practice; and if they be frequently used, they will facilitate as much the explanation of chemical action as

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75. What termination is used in other similar compounds of different bodies not acid?

76. What use is made of Latin and Greek numerals?

77. Define *acids*, *oxacids*, *hydracids*.

78. What terminations express the nature of acids?

the use of figures has simplified the operations of arithmetic. The following rules are to be carefully observed:—

85. The sign = is used to signify that the substances placed before it can produce, or can be resolved into, those placed after it.

86. Each dot prefixed to a symbol indicates 1 equivalent of oxygen. A dot is frequently used instead of O for oxygen.

87. Compounds are represented by the symbols of their elements. SFe = Sulphuret of Iron, is composed of sulphur and iron.

88. A figure prefixed to any symbol or symbols multiplies all that follow, unless a new sign intervene; thus, $2{\cdot}H\vdots S = 2{\cdot}\quad + 2\vdots S$. A small figure placed after any symbol indicates that it alone is to be multiplied; it does not refer to any other symbol, thus: $H^2C = 2H + C$.

89. Brackets are often used in representing complicated combinations; for example, $[2HC^2N + C^2NFe] + 2{\cdot}K$ = Ferrocyanic Acid + 2 potassa. A figure prefixed to any symbols placed between brackets multiplies them all, whether signs intervene or not: $2[2\vdots S + {\cdot}K] = 4\vdots S + 2{\cdot}K$.

90. In the symbolic and diagrammatic illustrations & is used to signify a substance added to another, but + is placed between substances already in combination. Thus, $\vdots S \& {\cdot}K$ signifies that sulphuric acid is to be added to potassa; but $\vdots S + {\cdot}K$ means sulphate of potassa, or sulphuric acid already combined with potassa.

91. Many vegetable acids are represented most conveniently by italic capitals, adding some succeeding letter where more than one have the same initial letter.

A. Acetic,	*Ct.* Citric,	*P.* Prussic,
B. Benzoic,	*G.* Gallic,	*T.* Tartaric.

92. All cases of chemical action represented symboli-

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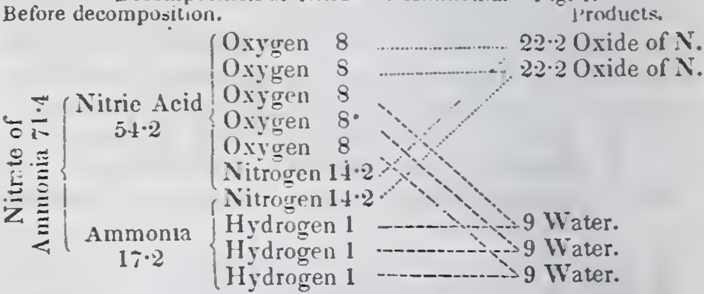
79. By what terms are watery compounds expressed?
80. What is a salt, and what is its base called?
81. Name the meaning of the suffixes and prefixes to the name of salts.
82. What are the signs in chemistry, analogous to figures in arithmetic, called?

cally should be extended on a slip of paper (or on a diagram board by the teacher) in the following manner, so as to enable the student to become familiar with the changes which take place. This mode of illustration has been proposed as being better suited to the present state of the science than the diagrams formerly used.

93. To the left place the names or symbols of the substances employed. Arrange, in the next place, the names of the component parts under each other, or of the different matters that are separated as the action proceeds. Lines traced from these, and uniting in a point, indicate those materials which combine. The lines are dotted when the products are gaseous, composed of smaller lines where they are liquid, and plain where they indicate the production or separation of any solid substance.

94. For example, the nitrate of ammonia is a compound of nitric acid and ammonia. Nitric acid contains five particles of oxygen and one of nitrogen, and ammonia consists of one particle of nitrogen and three of hydrogen. The weight of a particle of oxygen is 8, of nitrogen 14·2. that of hydrogen being 1. But when nitrate of ammonia is subjected to heat, all these particles take a new arrangement; two particles of oxygen with the two of nitrogen produce two particles of oxide of nitrogen, the three remaining particles taking the three of hydrogen. All these circumstances are rendered more distinct by the diagram,

Decomposition of Nitrate of Ammonia.—Fig. 1.



Symb. $\vdots N + NH^{3} = 2{\cdot}\dot{N} \,\&\, 3{\cdot}H.$

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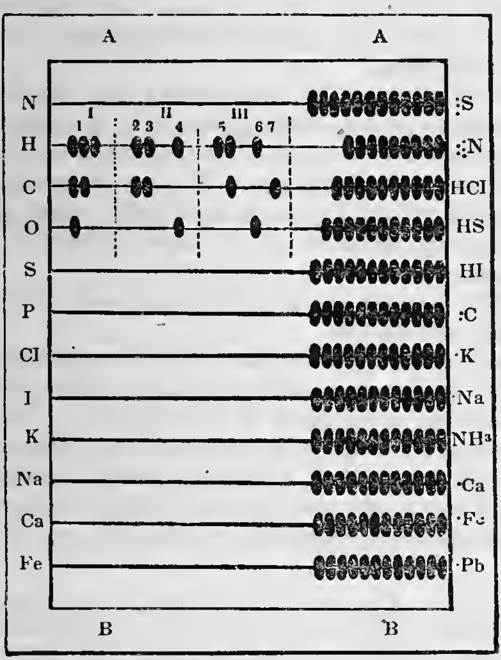
83. Explain these on the black board.
84. Describe the decomposition on this page.

the nitric acid and ammonia being represented towards the extreme left; then the number of particles in each compound and their relative weights. The lines proceeding from these indicate the new arrangement, those that coalesce pointing out the new products that are formed.

95. In studying the composition of compounds, the chemical abacus will be found very useful.

96. It consists merely of the common abacus so much employed by the ancients, and still used in different foreign cities, symbols representing elementary or compound bodies being placed along the side, as shown in fig. 2.

Fig. 2



97. When the abacus is used, the beads are placed to the right, if intended to represent elements, and to the

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85 What instrument is recommended here?

left when they represent compounds. The figure shows it arranged in the former manner, and six beads separated from the rest to illustrate the composition of alcohol. In I. they are all supposed to be united together; II. represents the same beads disposed so as to represent the formation of two particles of hydruret of carbon (2 and 3) and one of water (4); III. shows another arrangement of the same elements, namely, bihydruret of carbon (5), water (6), and carbon (7). The student may procure a chemical abacus for sixpence or a shilling, or he may make one for himself by stringing a few glass beads upon wire fixed in a wooden frame; he should practise frequently with it, till he becomes familiar with the various changes of which the most important compounds are susceptible, whether decomposed with or without the addition of other substances.*

98. In examining the composition and properties of many compounds containing gases, it is necessary to become acquainted with the bulk which their elements occupy as well as their weight. The following table should be frequently referred to, as it shows the composition by weight and by measure of the most important gaseous compounds.

The first column contains the names of different elements and compounds.

The second column contains the bulk or measure of the weight referred to in the succeeding column, hydrogen being taken as a standard of comparison. The square figure represents a whole measure, and the others indicate proportional quantities. Thus, in reading the sixth line, we say, Water in the gaseous state (steam) is represented by one measure, its equivalent weight is 9, and its symbol is OH.

* The use of the abacus for the above purpose was suggested on observing the facility with which many calculations were made with it in places where it is in daily use, and from the conviction that it will contribute greatly to facilitate the acquisition of a more precise knowledge of chemical changes.

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86. Describe the manner of using it.

The third column contains the weight of an equivalent quantity of each substance represented.

The fourth column contains the symbols of the elements and compounds represented in the preceding columns.

Gases and Vapours.	Equivalents by bulk.	Equivalents by weight.	Symbol.
Oxygen (half a measure),	▭	8	O
Sulphur (a third of a measure),	⅓	16·1	S
Phosphorus (half a measure),	▭	15·7	P
Hydruret of Carbon (half a measure),	▭	7	HC
Hydrogen (a whole measure),	□	1	H
Water,	□	9	OH
Nitrogen,	□	14·2	N
Oxide of Nitrogen,	□	22·2	ON
Carbon (hypothetical),	□	6·12	C
Carbonic Oxide,	□	14·12	OC
Carbonic Acid,	□	22·12	O^2C
Bihydruret of Carbon,	□	8·12	H^2C
Cyanogen,	□	26·44	C^2N
Sulphurous Acid,	□	32·1	O S
Sulphuric Acid (anhydrous),	□	40·1	O S
Hydrosulphuric Acid,	□	17·1	HS
Chlorine,	□	35·5	Cl
Iodine,	□	126·5	I
Bromine,	□	78·4	Br
Binoxide of Nitrogen (2 measures),	□□	30·2	O^2N
Ammonia,	□□	17·2	H^3N
Hydrocyanic Acid,	□□	27·44	HC^2N
Hydrochloric Acid,	□□	36·5	HCl
Hydriodic Acid,	□□	127·5	HI
Hydrobromic Acid,	□□	79·4	HBr

87. Explain the table and its uses.

CHAPTER IV.

CRYSTALLIZATION.

99. In many chemical operations, bodies are often procured in regular symmetrical forms, termed *crystals;* and the process by which they are formed is called *crystallization.* Crystals are generally procured in one of the following modes:—

I. By melting solids, or converting them into vapour by the application of heat, allowing them to return slowly to the solid form.

II. By slow deposition from fluids in which they have been dissolved.

100. Before crystallization can take place, the particles of the matter to be crystallized must have free liberty of motion, and the attraction that formerly bound them in a solid mass being now permitted slowly to resume its force, they gradually attract each other by those extremities, sides, or angles, which determine the production of regular figures, according to the relations or tendencies with which they have been created by the Author of Nature. Heat, or the action of a solvent, is required in the first instance to give that freedom of motion which is essential to crystallization; and when their influence is slowly withdrawn, the particles have time and opportunity to assume that position which developes crystals.

101. If the action of the heat, or of the solvent, be suspended suddenly, the particles resume the solid form indiscriminately; and however regular the form of each may be, still, from the want of a regularity in their aggregation, nothing but an amorphous mass is observed.

102. The first portion that becomes solid in the process

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88. What are the symmetrical forms of chemical bodies called, and what is the name of the process?

89. Describe the two methods.

90. What agencies favour this process?

of crystallization, draws other particles successively to it; these do not fall indiscriminately upon each other, but attach themselves by one part rather than by another to those already deposited, according to properties communicated to them when they were originally formed. The extremities of the particles are considered to draw to each other exactly in the same way as a suspended magnetic needle points to the north and south, while it refuses to turn in any other direction.

103. Of late years, numerous cases have been pointed out where the form of solids has been changed, without inducing fluidity previously either by heat or other means. If the yellow binoxide of mercury be touched by any hard substance, a creeping motion is observed among its particles; they assume a new arrangement, and the colour is changed to bright scarlet. In sulphur and many salts at ordinary temperatures, and in iron and other substances at a high temperature, similar changes have been observed; and even in masses of particles merely mechanically mixed with each other in the first instance, a crystalline arrangement is often subsequently developed.

104. In such cases, crystallization may sometimes be attributed to the alternate action of various temperatures, such as occur in the atmosphere at the surface of the earth; and these, by favouring expansions and contractions, give the particles in the small contiguous masses an imperfect opportunity of cohering together. In other cases, moisture, or an electrical action, has been supposed to induce the change that takes place.

105. The minute particles, or atoms of matter, are all considered to have fixed and definite forms, so that, were a sufficiently powerful magnifying glass constructed, it is considered that these would be distinctly seen, whatever might be the nature of the substance examined. In all crystals a nucleus is observed, which is often very different from the external form of the crystal. It is obvious that

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91. Describe it.
92. To what circumstances is it owing when occurring spontaneously?

crystals of the same kind of matter may be obtained in a great variety of forms, according to the manner in which the particles are disposed upon each other, in the same manner as a builder can produce a vast variety of architectural figures with bricks of the same size and shape, according to the manner in which he arranges them. Several hundred varieties of crystals of carbonate of lime have been pointed out; but if any of these be broken with a gentle blow, so that the different laminæ may separate, innumerable fragments of a rhomboidal form are obtained, and no other shape is presented.

106. A number of groups of different substances have been pointed out, the forms of whose particles are considered to be similar. They are said to be *isomorphous*, and when they combine with different portions of the same body, the forms of the crystals of the new compounds are also isomorphous.

107. Crystallization is observed in all the products of the mineral kingdom, where they have not been ground down by a rude mechanical force, or separated in the first instance in particles too minute to admit of their form being recognised.

108. Melt 2000 grains of sulphur by applying heat cautiously. After placing it in a flask, then remove the heat, pour out half of the liquid when the other half has consolidated, and observe the crystals of sulphur.

109. Put alum into 8 or 10 ounces of water at a boiling heat, in a glass or earthen vessel, adding it so long as it is dissolved. Allow the liquid to cool; crystals are deposited. [By suspending a basket made of wire in the hot solution of alum, the crystals will form upon the wire; or the same experiment may be performed with sulphate of copper and many other salts of different colours.] Hot liquids dissolve more of most substances than those that are cold, and if charged when warm with as much of any of them as they can dissolve, part is deposited on cooling.

110. Expose a solution of oxalic acid or glauber salt to

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93. What name is given to groups of similar particles?
94. Name the experiments here cited.

the air for some days on a shallow plate; the water is in part slowly removed, and crystals appear. By reducing these substances to powder, and shaking them with water so long as any is dissolved, a solution is very quickly procured.

111. The state of the air on some occasions has a great influence on the crystallization of salts from watery solutions. So well is this known to the manufacturer, that the same language is in familiar use in many crystallizing establishments as is adopted by the farmer; the workmen sometimes looking forward to the condition of the atmosphere—particularly where many salts are in the same solution, one of which is expected to crystallize before the others—with the same anxiety, and talking of the crops of epsom or of glauber salts much in the same way that the farmer speaks of his crops.

112. The influence of the air on crystallization is beautifully shown by heating glauber salt in a flask half full of boiling water till no more is dissolved, corking the flask when the air has been expelled by the steam on boiling the solution, and then removing it from the heat. The solution does not crystallize on cooling; but if the cork be now removed, the crystallization commences as the air enters, extending rapidly till a solid crystalline mass is formed. The air operates principally by abstracting some of the water of the solution, and causing the precipitation of a minute crystal, from which the crystallization proceeds till it ramifies through the whole mass. When the weather is warm, and the crystallization does not ensue quickly on taking out the cork, the introduction of a small crystal usually determines it immediately by agitating the fluid.

113. Heat a tinned iron-plate before the fire, or over a lamp, till it is as warm as may be necessary to cause water dropped upon it to evaporate quickly with a slight hissing noise. Let the tin with which the iron is coated be then washed with a cloth well moistened with a mixture composed of water 1 ounce, muriatic acid 1 drachm,

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95. What circumstances influence or hasten crystallization?

and nitric acid 1 drachm. The cold fluid causes the hot tin suddenly to assume a crystalline form, and as the acids act upon the external particles of the tin, and expose those below, the crystalline arrangement is beautifully seen. When varnished, it retains its lustre; the varnish may be coloured of any tint that may be required.

114. Crystals and other solid substances which attract moisture from the air and become fluid, are said to *deliquesce;* those that lose moisture under the same circumstances, and assume the appearance of a powder, are said to *effloresce.*

CHAPTER V.

HEAT OR CALORIC.

115. Chemical action being affected powerfully by heat, light, and electricity, it is necessary to attend to their influence before entering upon the history of individual substances. All the effects commonly attributed to heat are produced by its entering and attaching itself to the substance affected, while those which are said to be caused by cold, arise in reality from a portion of heat leaving those substances with which it has been associated. In common language, the term heat is employed in two ways, indicating either the sensation of warmth, or the cause of that sensation and of such other effects as are attributed to it. The term *caloric* was introduced to signify the matter or power of heat alone.

116. No agent is more universal in its influence on matter than caloric. There is nothing in this globe that we can see or touch that does not contain it. Were caloric withdrawn entirely from matter, it is impossible to conjec-

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96. Describe the experiment upon tin.
97. What are the changes of crystals called?
98. Define cold and heat.

ture what appearance it would present, but even with a more moderate reduction in its amount, the whole ocean would be changed into ice, and universal death would ensue both in the animal and vegetable kingdoms. On the other hand, were its intensity greatly increased, destruction would equally attend animal and vegetable life, the whole ocean might be dissipated in vapour, and even the solid matters that compose the earth might be volatilized by its powerful agency. There is nothing, however, whose precise relation to the minute particles or atoms that compose masses of matter is more imperfectly understood; and whether it pass from the sun to the earth, from the open fire to the human frame, from the furnace of intense heat to the materials used in the operations of art, or be developed in a more subtle form by the various changes in the matter that accompany a living action in the bodies of animals or in plants, still no clue has been obtained as to the manner in which it is associated with their minute particles.

117. Caloric not only induces a vast variety of modifications in the properties of individual substances, according to the proportions in which it is communicated to them, but is also distinguished by certain general effects which it produces, more especially *expansion*, *liquefaction*, *vaporization*, *evaporation* and *incandescence*.

118. No one has been able to collect heat and show it by itself; it is invisible, has no appreciable weight, and sooner or later it can penetrate every thing with which it may be surrounded. It is known only by its effects, and is considered a peculiar fluid, easily thrown into vibratory movements.

119. Heat tends always to pass from the hotter to the colder substance, till both bodies acquire the same condition in this respect, when they are said to attain an *equilibrium* of temperature.

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99. What is the use of the term caloric?
100. What reflections does its universality suggest?
101. Name the general effects of caloric.
102. What is the theory concerning its nature?
103. Define equilibrium, and temperature.

120. The *temperature* of any substance indicates its disposition to communicate heat to, or remove it from, any standard of comparison; if the temperature of the body be taken as a standard of comparison, those substances at a higher temperature communicate heat to it, while those at a lower temperature remove heat from it.

EFFECTS OF HEAT.

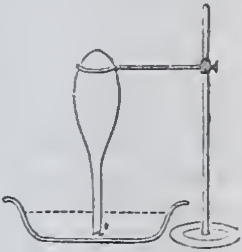
121. **Expansion.**—Bodies, with few exceptions, are expanded by heat; gases expand most, liquids come next and solids last of all. When heated from 32° to 212°, ai expands 3-8ths of its volume, alcohol 1-9th, water 1-22d and hammered iron 1-237d.

122. Measure the length of a cold iron rod or bar; hea it to redness, and it will be found longer. [The smith heats the tire to expand it, and after applying it upon the wheel suddenly cools it to make it contract firmly, by pouring water upon it.]

123. Fill a long narrow-necked flask nearly full of alcohol, and put it into boiling water; the alcohol as it expands rises in the neck of the flask.

124. Pour boiling water upon the same flask full of air after inverting it in water (it may be supported or steadied in this position by a ring of the retort stand); part of the expanded air is expelled; and water is forced back by the pressure of the air to supply its place, when it again becomes cold.

Fig. 3.



125. **Exceptions.**—Water contracts as it is heated from 32° to 39½°. Many solids contract as they are melted by heat, expanding again as they become solid—as ice, iron, antimony, bismuth, and many salts.

126. The communication of heat causes expansion to take place with great force; iron-bars, for instance, often

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104. In what proportion do different forms of matter expand by heat?

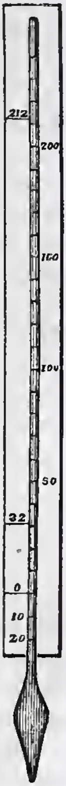
105. Name the experiments cited.

106. What are the exceptions?

cause rents in furnaces as they expand. A tough solid, such as iron, contracts with great force on cooling. Water, and other melted solids, expand with great power as they become solid, bursting the vessels containing them when they are not allowed to escape in part by any aperture. A phial full of water, and corked tightly, bursts as it is frozen.

127. The common *thermome'ter* contains a fluid which indicates the communication of heat, by expanding and rising in the stem, and the removal of heat (cold) by contracting and descending. Thermometers are graduated, and made to correspond with each other by observing the different points to which the fluid rises in freezing water and in boiling water. [The scale here described is that of Fahrenheit, and is used in America as well as Great Britain almost exclusively.] The space between these is usually divided into 180 parts, 32 being placed opposite the point where the water freezes, and 212 opposite the point where the fluid stands when the water boils. Similar spaces are marked off upon the stem above and below these points, and numbered accordingly. It was at one time imagined that the greatest cold could make the fluid fall only 32 such spaces below the freezing-point, the place to which it then fell being termed *zero*,* and the notation commencing there. But much greater degrees of cold exist at different parts of the globe in winter, and may be produced artificially, so that the fluid in the stem of the thermometer often descends below that point, and is then said to be at so many degrees below zero. Thus, 52 degrees below the freezing-point, or 20 degrees below zero, is usually written—20°.

Fig. 4.



[* This zero indicates the temperature produced by melting snow and salt together, which is 32° colder than ice.]

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107. Name instances of the force of expansion.
108. What instrument is constructed upon this principle for measuring temperature?

128. LIQUEFACTION.—Heat is considered to be the cause of liquefaction, melting all solids which it does not previously decompose. When any solid melts, much heat is required to effect this change in its form after it arrives at the melting-point. Pour some boiling water upon ice at 32 degrees; the ice melts rapidly, but the water produced is no warmer than the ice; the heat is consumed in melting the ice, and is said to become *latent*, as it does not affect the thermometer. Pour boiling water upon ice-cold water, and the temperature is immediately increased.

129. When a fluid becomes solid, it gives out without cooling the heat which had rendered it fluid; the change proceeds slowly, as so large a quantity of heat must be withdrawn. As much heat is required to melt ice as would raise the temperature of an equal weight of ice-cold water by 140 degrees; it melts, accordingly, with extreme slowness. Were no heat to become latent as snow and ice melt, they would liquefy with great rapidity, and produce inundations that would in many places be altogether destructive of animal and vegetable life.

CHAPTER VI.

VAPORIZATION—SPONTANEOUS EVAPORATION, &c.

130. The term *vapour* is applied chemically to all thin, attenuated, and gaseous substances, such as can be formed by the action of heat on solids and liquids, and can be restored again to the liquid or solid form by withdrawing the heat communicated to them.

131. *Gas* is a term applied to matters such as air, equally thin and attenuated as vapours, but not met with in a condensed form under ordinary circumstances, and

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109. Whose scale is described here?
110. What fixed points are made?
111. Does every form of heat affect the thermometer?
112. Describe the experiments with ice.

not capable of being reduced to the liquid or solid form, except by such intense cold or extreme pressure, that only part of them have as yet been brought to these conditions. They are considered as vapours requiring a temperature for condensation so low that many have never yet been seen in the liquid form. The air we breathe is thus considered to bear the same relation to a peculiar liquid and solid not yet discovered, that steam does to water and ice. It is the steam of a solid that no one has yet seen, but which even at ordinary temperatures is far beyond the point at which, were it previously liquefied, it would boil and disappear in vapour. Sulphurous acid gas may be liquefied by a very moderate cold, namely, 14 degrees of Fahrenheit. The most interesting experiments on the liquefaction of gases have been made with the carbonic acid gas. When large quantities of the liquefied gas are allowed to escape from an appropriate apparatus, intense cold is produced, and one portion is frozen by the cold developed as the other evaporates. The frozen carbonic acid is a white solid as light as snow. Though reduced to a temperature of —180°, it may be put into the mouth without injury, producing a very peculiar sensation, as it has the sharpness of ginger-beer, without moisture or any peculiar flavour, feels perfectly dry, and passes at once from the solid to the gaseous form. Were it capable of abstracting heat more perfectly, as mercury or other metals, it could not be brought near the skin or mouth without injury.

132. There are a number of gases, all differing more or less from each other, in the same manner as different solids or liquids; and, according to the opinion now universally entertained, they may be regarded as solids which have been melted, evaporated, and heated beyond their boiling-point.

133. The temperature at which different liquids boil is very various, as well as the density of the vapour, and the amount of heat required to produce it; water, however,

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113. What is vapour? gas? the difference?

114. Have any gases been rendered fluid or solid, and by what means?

may be taken as an example to illustrate the general nature of the process of vaporization.

134. *Vaporization* signifies the rapid production of a thin vapour, as when water is boiled and produces steam.

135. Water boils at 212 degrees. and does not become warmer as it boils, the heat applied being consumed in producing a change of form. Hence, it is not economical to boil any substance quickly which may only require exposure to a boiling temperature, as all the heat that may be consumed in producing the vapour must cause an unnecessary expenditure of fuel.

136. Put a thermometer into water, mark where the fluid stands in the stem as the water boils, and observe that it rises no higher, however long the boiling may be continued.

137. As much heat is required to produce steam from boiling water, as would elevate the temperature of an equal weight of boiling water by 1000 degrees,* were it still to remain fluid. Steam, though it contains so much heat, is always at the same temperature as the water from which it rises, if the pressure of the atmosphere be the same, the caloric that produces it being engaged as it were in sustaining the change of form induced in the water, without being able to produce any increase in the temperature. The heat that produces the steam is said to become latent as in the liquefaction of solids.

138. Steam is transparent, colourless, and invisible, like the air. The white cloudy-looking matter usually called steam, is moisture produced by the condensation of steam. Steam occupies 1696 times as much space as an equal weight of water, and as it expands with great force, it often bursts and destroys vessels in which it is confined. When the power with which it expands is carefully regu-

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* Different estimates have been given of the precise amount of heat that becomes latent during vaporization, some exceeding and others being less than the amount stated.

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115. Do all fluids become vapour at the same temperature?
116 When they boil, does the temperature go on increasing?
117 What becomes of the heat in vaporization?
118. Describe steam, and the extent of its expansion.

lated, so as to produce motion in machinery, it forms the most powerful engine man has invented, namely, the steam-engine.

139. When steam is exposed to cold, it condenses into water, giving out all the heat by which it was produced; and hence the large amount of heat it may be made to convey, and the severe burn it produces when condensed on any part of the body.

140. Boil a small quantity of water in the flask represented in fig. 3; put in a cork when the air is expelled, and open the flask cautiously under water; the steam, which previously nearly filled the flask, being suddenly condensed, the pressure of the air forces up water to supply its place.

141. Water boils at a lower temperature than 212 degrees, when the air is not allowed to press upon it; fill the flask already alluded to (fig. 3) one-half full of water, boil it briskly, and cork it while the steam is escaping, removing the heat immediately. The cold air condenses the steam, the cork prevents the air from entering, and the water thus relieved from pressure begins to boil, the heat already in it being sufficient for that purpose. Put the flask into cold water; the ebullition then increases, the steam being still more effectually condensed. Put the flask into boiling water; the steam being no longer condensed presses upon the water, and prevents it from boiling.

142. If steam be not allowed to escape, and heat be continually applied by the fire, a higher and higher temperature is required to make the water boil, and the steam formed acquires more and more power, each successive portion compressing much of what had been already formed. It is then called *high-pressure steam*, as it presses upon the sides of the boiler with great force. Boilers in which such steam is produced ought always to be provided with valves which the steam can push open,

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119. How is this rendered useful?
120. Explain why steam burns more than boiling water.
121. Can water be made to boil below 212°?
122. What do we mean by high-pressure steam?

and by which it may escape before it becomes strong enough to burst the boiler.

143. It is a curious circumstance that steam always contains the same amount of heat, whatever be the temperature at which it is formed: the latent heat required for its production being less and less as the temperature at which it is formed is increased by preventing its escape.

144. The greater the pressure to which water or any other liquid may be exposed, the more elevated is the temperature required to produce vapour, the more dense is the vapour formed, and the greater is its explosive or moving power.

145. Fig. 5 is a section of part of a boiler where the safety-valve is placed, the valve being loaded with a weight which the steam can raise before it acquires strength to burst the boiler. In examining the construction of boilers, the different parts noted in fig. 6 should be attended to: *a*, *b*, the body of the boiler, filled with water

Fig 5.

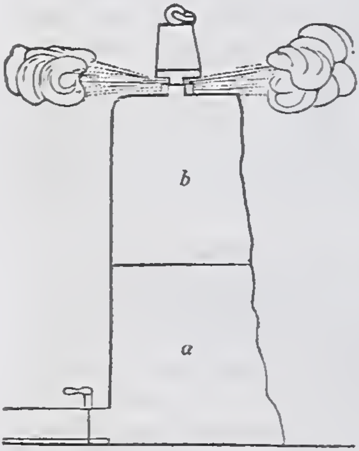
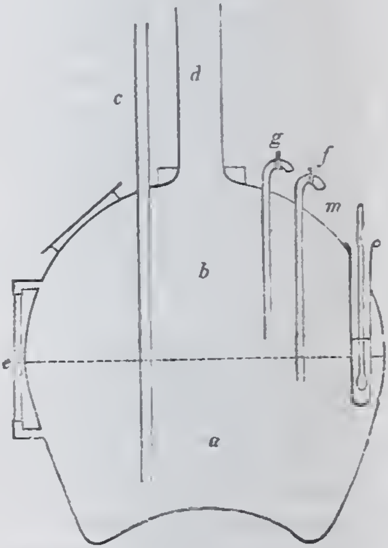


Fig. 6.



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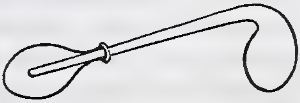
123. Describe the effects of pressure.

and steam; *c*, a pipe by which water is forced into the boiler; *d*, the steam-pipe; *e*, a glass tube or gauge placed so that the steam and water can enter freely into it, the water being always at the same height in it as in the interior of the boiler; *f*, *g*, two pipes placed so that the quantity of water in the boiler may be ascertained, when the glass tube is not used; if water come from both, on opening the stopcocks, and when there is abundance of steam in the interior of the boiler, there is too much water, and if steam be disengaged from both, then there is too little; the boiler should be charged so that one gives steam and the other water, the level of the water in the boiler being between the extremities of the tubes within the boiler; *m*, a thermometer, indicates the temperature in an iron tube containing mercury.

Fig. 7.



146. Distillation consists in the production of vapour by heat, which is afterwards condensed. The vessel in which the vapour is produced is called a *retort;* that in which the condensed vapour is collected must be kept cold, surrounding it with a cloth, and moistening it with water; it is termed a *receiver.* Fig. 7 represents a retort and a receiver.

147. When a large quantity of fluid is to be distilled, it is introduced into a vessel called a *still* (fig. 8), the pipe from it leading to a vessel termed the *refrigeratory*, as it is filled with cold water; the vapour is condensed in the coiled pipe, or *worm*, as it is often called, and escapes through it into a receiver placed below it.

148. *Spontaneous evaporation* is the term usually employed when vapour is produced slowly from a fluid, and without ebullition, as when water disappears from any moist surface. Water evaporates in large quantity from the surface of the ocean, and from the earth also, eventu-

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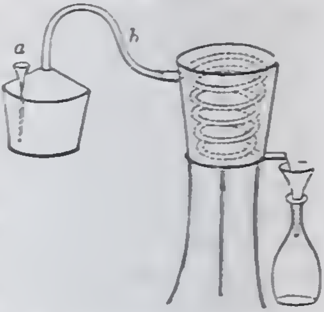
124. Explain the diagrams.
125. What is distillation?
126. Define *retort, receiver, still, refrigerator, and worm.*
127. What is meant by *spontaneous evaporation?*

Fig. 5.



ally producing the clouds, or condensing in the form of rain and dew. Snow is formed when the vapour is frozen at once, and hail when rain is first produced, and then congealed by the cold.

149. Evaporation is always accompanied by the production of cold, when no heat is directly applied; the heat necessary for the production of the vapour is then derived from surrounding objects, and from part of the liquor evaporated.

150. Pour some ether, or any other volatile fluid, on the back of the hand; great cold is perceived as it evaporates. If we blow upon it, the vapour resting on the surface is rapidly removed, evaporation proceeds more quickly, and a more intense degree of cold is produced. [In this way any small animal, as a mouse, may be frozen to death, by sprinkling ether upon it and hastening its evaporation by blowing it with a bellows.]

151. Evaporation proceeds more and more quickly the higher the temperature; the greater the extent over which the evaporating fluid is spread, the less the pressure of the air, and the nearer the evaporating substance approaches the boiling point. At the summit of high mountains, where the pressure of the air is less than at the surface of the earth, water boils at a lower temperature than 212 degrees; it is there above a large portion of the air which presses upon the surface of less elevated regions.

152. A current of air, when not loaded with moisture, promotes evaporation; hence the rapidity with which a wet surface generally dries on a windy day, the vapour resting upon it being pushed away, and a new portion rapidly formed.

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128. What is the difference between vaporization and evaporation?
129. What experiment produces cold?
130. What favours evaporation?

153. Moisture is separated from the air in which it is diffused, by a reduction of temperature. Sometimes it forms innumerable small vesicles; the mode of their production is not known. When they are associated together in large quantities, they produce clouds. The water evaporated from the surface of the ocean, &c., being purified from the materials with which it may have been mixed at the surface of the earth, and falling down afterwards in the form of rain, hail, snow, dew, or hoar-frost, becomes fitted for the various purposes for which it is so necessary in the animal and vegetable kingdoms.

154. Instruments for determining the amount of moisture in the air have been invented; they are usually termed hygrometers.

155. The nearer the equator, the greater the annual fall of rain, and the less the number of rainy days. At Granada, 12 north lat., the rain which falls annually would cover the surface to the depth of 126 inches, were it all to be deposited at the same time. In this country, it is calculated that the annual fall of rain would, on an average, cover over the surface to the depth of 32 inches; which is rather more than is usual in America.

EXOSMIC AND ENDOSMIC MOVEMENTS.—DIFFUSION OF GASES.

156. All bodies brought into close contact generally produce

A mechanical intermixture,
A mechanical adhesion, or
A chemical union.

157. One of the most important kinds of intermixture hitherto noticed, is that which takes place in fluids of different qualities approximated to each other so as to come into actual contact when they begin to act, if they have any chemical attraction for each other, even if membrane or any porous substance be interposed, provided it be

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131. What natural phenomena are here cited?
132. Define hygrometer.
133. What is said here of the proportion of rain?
134. What are the effects of bringing bodies into close contact?

moistened with one of them. A variety of circumstances determine the currents, more particularly the permeability of the interposed fibre, membrane, or porous cup, the movement taking place most largely from the liquid to which the porous structure is most permeable.

158. The movement produced in this manner appears to depend principally upon the attraction exerted between the particles of the different fluids employed, as they meet in the porous membrane. When the movement proceeds from the interior of any cavity, it is termed *exosmosis.* But the movement of the other fluid inwards is termed *endosmosis;* a portion of one always enters as a part of the other presses outwards.

159. The *diffusion of gases* is an action similar in some respects, but very different in others. It consists in the gradual intermixture of gases, in a proportion bearing a relation to their specific gravity, when they are placed in communication with each other. This operation, as in the case of fluids, often takes place with great force, the vessels bursting where the action advances most rapidly; they are made of bladder or similar materials. Diffusion takes place not only through porous and membranous solids, but may be often observed in situations where water is completely retained, as through a cracked glass, or through a tube of glass having the extremity filled with plaster of Paris, air passing freely through these in many cases when water cannot pass.

160. To illustrate the diffusion of gases, procure a glass tube 12 or 18 inches long, and half an inch or an inch in diameter. Obstruct one end with a plug of plaster of Paris about half an inch thick; fill it with hydrogen gas by means of a long narrow tube, through which the hydrogen is introduced from a bag or gasometer, holding the tube perpendicularly with the plugged extremity uppermost. On withdrawing the internal tube, and placing the open extremity of the other under water, the hydrogen begins to escape so quickly by diffusion from the plugged ex-

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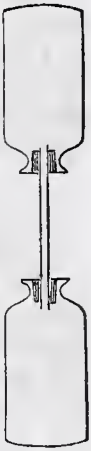
135. Define exosmosis and endosmosis.
136. What is said of the diffusion of gases?

tremity of the tube through the plaster of Paris, that the pressure of the atmosphere forces the water up to the height of several inches to supply its place; after a time, however, a proportionate quantity of air enters, and the water regains its original level.

161. The diffusion of gases may also be illustrated in a very simple manner, by taking a bottle filled previously with hydrogen gas, and another with carbonic acid gas, connecting them together, as represented in the figure, and inverting the bottle with the hydrogen over the other containing the carbonic acid. Notwithstanding the lightness of hydrogen, and the heaviness of carbonic acid gas, still, from the operation of the diffusive power which has been described, part of the light hydrogen descends into the lower bottle containing the carbonic acid, while, at the same time, a corresponding portion of heavy carbonic acid ascends and mixes with the hydrogen in the upper bottle.

Fig. 9.



162. Incandescence.—All solids and fluids which are not converted into vapour at a less elevated temperature, become luminous when heated to 800 degrees in the dark, or when heated to about 1000 degrees in daylight. A red light appears at first, and gradually passes to a white as the temperature increases. This is observed equally in combustible solids, as charcoal, and in stony or other matters which do not burn; they are then said to be in a state of *ignition* when they are red hot, and *incandescent* when they are at a white heat.

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137. What experiments are cited?
138. Define *incandescence* and *ignition.*

CHAPTER VII.

COMMUNICATION OF HEAT.

163. Caloric is communicated by *conduction* and *radiation.*

164. When caloric passes slowly from one portion of matter to another in contact with it, it is said to be *conducted,* and the process is termed the *conduction of caloric.* Metals are the best conductors, then liquids, and lastly gases. Gold, silver, and copper, are the best conductors among solids; glass, bricks, and many stony substances, are very bad conductors; and porous spongy solids, as charcoal, hair, and fur, are the worst.

165. Put one end of an iron rod into the fire; the heat soon passes to it, and along its particles to some distance from the fire. Put a glass tube, or piece of wood of the the same size as the iron, into the same part of the fire; the heat extends a very little way beyond the part touching the fire, both these substances being bad conductors.

166. Many of the more familiar phenomena of nature and of art depend upon the conducting power of different bodies. Thus, iron and cotton, if cooled to the same temperature below that of the body, do not affect it equally when applied to it; the iron produces the strongest impression, as it conducts the heat most rapidly away. Again, if they be raised to a high temperature, the iron still produces the strongest sensation, communicating heat most rapidly. In short the good conductor always produces the greatest effect, either by communicating heat more freely than the cotton or by removing it.

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139. How is heat communicated? define these terms.
140. Name good and bad conductors, and the experiments cited.
141. What phenomena illustrate it?
142. Describe the effects of heat upon the upper and lower portion of a fluid.

167. Clothing is generally made of bad conductors, that the heat of the body may not be conducted quickly to the surrounding air. [Hence the object of woollen clothing is not to keep out the cold, but to keep in the heat of the body.] Furnaces, where great heat is required, are built with porous bricks, which are very effectual in preventing the escape of heat; but when a stove is placed in the middle of any apartment, the fuel is surrounded with iron, that the heat may be quickly conducted to the air. The ice in an ice-house is surrounded with bad conductors, to prevent warm air coming in contact with it, or transmitting heat to it.

168. When heat is applied to the upper portion of any liquid, expansion generally ensues, and it becomes lighter than the rest; it remains, therefore, resting upon the colder and heavier part. This may be easily shown by boiling the upper portion of water in a long glass tube, applying heat by a spirit-lamp. If the heat be applied near the bottom of the tube, fig. 10, the colder portion from above soon sinks below the hot expanded fluid, and pushes it up, so that currents are continually produced, till the whole fluid is heated to the same point. If the water at the bottom of each tube be coloured, that in fig. 10 is soon

Fig. 10.

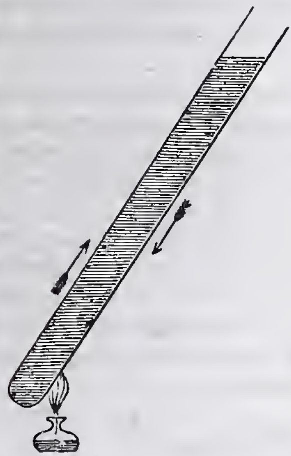
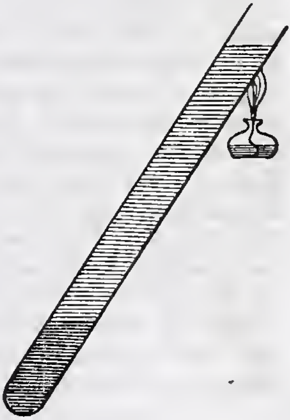


Fig. 11.



seen to mingle with the water above it, but the coloured water in the other does not move.

169. If heat be applied to a glass vessel containing water, as represented in fig. 12, the water in contact with the warm glass expands, and hence becoming lighter, it rises to the surface, its place being quickly filled by the colder water in the centre which descends and pushes up the warm water at the sides.

Fig. 12.

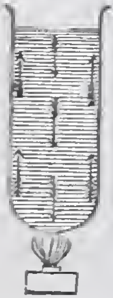
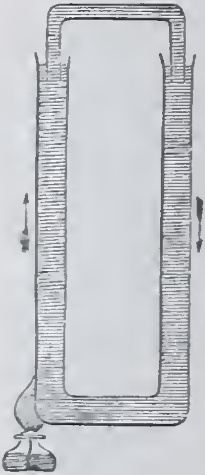


Fig. 13.



170. If water be placed in a glass tube bent in the manner represented in fig. 13, and the water at the extremities be connected by another smaller and similar tube, then, on applying heat to the lower part of one of the limbs, the water begins to move in the manner shown by the arrows. The colder and comparatively denser and unexpanded water in the one limb, descends and pushes up the warmer water in the other limb, assuming the place of the hot water. Subsequently, it becomes heated in its turn, and thus the circulation is continued so long as any inequality of temperature is sustained.

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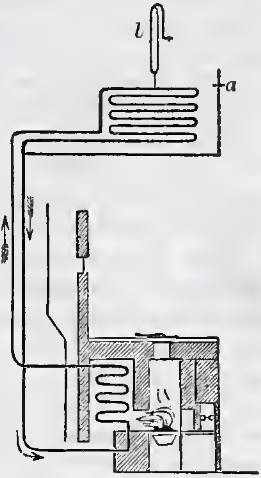
143. Name the experiment cited ?
144. To what practical use is this applied ?

171. On the same principle, boilers are now constructed which convey heat from the fire to which they are exposed through tubes or iron cases to the air of different apartments, diffusing a gentle and equal warmth or a sharper heat, according to their structure and the amount of heat to which they are subjected.

172. Such apparatus may be obtained of two kinds; the first, according to Mr. Price's patent, never heats the air in contact with it above 212 degrees. In the other, introduced by Mr. Perkins, the water can be heated to a much higher temperature, in cases where this may be considered desirable. The annexed figure illustrates the general arrangements adopted according to his system. It consists merely of a series of coils of tube, part of which are placed where the water is to receive heat, and the rest where the heat is to be evolved. *a* represents a pipe for introducing water, and *b* an expanded portion of tube, intended to contain any excess of water when expanded by the heat.

Fig. 14.



173. Similar movements take place in the air.—See the section upon Carbon, where illustrations are given of the currents produced by common fire.

174. Caloric is said to be *radiated* when it passes with great velocity from the sun, or from any warm body at the surface of the earth, moving through space, or through the air. It is believed in this case to move with the same velocity as light, namely, 192,000 miles in a second. Caloric is also radiated from warm bodies that are not luminous, as from the hand, or from hot water.

175. Radiant caloric is absorbed when it falls upon bodies having painted or rough surfaces, such as are pre-

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145. What of the velocity of radiation?

sented by bricks and other porous solids, by many kinds of stony matter, and numerous animal and vegetable substances. and elevates their temperature as it is taken up. But brilliant and polished metallic surfaces absorb little heat ; they reflect or turn it back again.

176. Take a piece of common tin-plate, and place it before the fire, it reflects most of the radiant heat, and becomes warmer with extreme slowness. Make the surface rough with a file or sand-paper. cover it with lamp-black, or black paint ; it now absorbs heat quickly when exposed to the fire, and soon becomes warm.

177. Those bodies which are most powerful in receiving radiant heat when it falls upon them, are equally powerful in emitting it when they are warmer than surrounding objects. Thus, a vessel with hot water, having a rough porous, or painted surface, cools much more quickly than when the surface is brilliantly metallic.

178. All bodies at the surface of the earth lose heat by radiation in a clear evening ; they radiate more or less heat according to the nature of the surface ; those that radiate most become colder than the others, and on these more dew or hoar-frost is deposited, the air coming in contact with them being cooled to the greatest degree, and unable, therefore, to retain all the moisture previously associated with it. The green leaves of vegetables are powerful in radiating heat, and are accordingly covered with the dew during the night, which is so necessary for plants when there is no rain.

179. In a cloudy night, as heat does not escape by radiation from the surface of the earth, the temperature never falls so much as in a cloudless sky.

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146. What conditions reflect or absorb heat ?
147. Name the illustrations.
148. What phenomena are thus explained ?

CHAPTER VIII.

DISTRIBUTION OF CALORIC.

180. Caloric is unequally distributed over the globe. At the equator the average temperature is 82½ degrees; at the poles it is believed to be about 13 degrees below zero. The higher we ascend in the air, the colder it becomes; the summits of very high mountains are always covered with snow. The interior of the earth is generally believed to be at a very elevated temperature: many consider the numerous volcanoes that appear at its surface to arise from a central fire.

181. Caloric tending always to an equilibrium, the heat at the warmer portions of the surface of the globe is carried in part to those that are colder, by currents in the air and in the ocean, so that the extreme severity, both of heat and cold, is thus mitigated.

182. The amount of caloric is not the same, even in equal weights of different bodies at the same temperature; as a wide jar requires more liquid to fill it to a certain height than is necessary to fill a narrow jar to the same height, so, many different bodies require more heat than others to elevate their temperature to a fixed point. Take a small jug of boiling water, and mix it with an equal bulk of cold water, previously placed in a flask or basin, and examine the temperature with a thermometer. Then mix equal bulks of boiling water and cold oil in another vessel, and the temperature of the mixture will be greater than before; the heat which the boiling water loses, elevating the temperature of the oil by a greater number of degrees than an equal bulk of cold water.

183. Production of High Temperatures.—Heat is

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149. What of the distribution of caloric?
150. What is a uniform tendency of heat?
151. How is this illustrated?

developed principally by burning inflammable substances. —(See Air and Carbon.) It may also be excited by mechanical action and by electricity. A most intense heat is produced when the rays of the sun are collected by a burning-glass, which bends the heat passing through it in such a manner that much of it falls upon one point.

184. Hammer a piece of iron on an anvil, it soon becomes very warm. Rub a thin piece of phosphorus, not greater than a quarter of a grain, with a piece of glass; after placing it in paper, it soon inflames when exposed to the air.

185. Production of Low Temperatures.—By placing volatile fluids where they evaporate rapidly, as in a current of air, considerable cold is produced. Pour any volatile fluid on the hand, and blow upon it; it evaporates with great rapidity, producing cold as the vapour formed removes heat from the hand. (See Vaporization and Spontaneous Evaporation.)

186. Again, solids which are rendered fluid without the application of heat become very cold. Mix two parts of snow or pounded ice with one of salt; the mixtures soon becomes fluid, and the temperature falls 41 degrees below the freezing-point of water, if large quantities be used, and the snow and salt be in a minute state of division.

187. Mix 16 ounces of water with 5 of nitre and 5 of sal-ammoniac in fine powder; the temperature falls about 40 degrees as the salts dissolve in the water. Boil off the water, and collect the dry salts, which may be used again and again for the same purpose. [These are denominated frigorific mixtures.]

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152. What of high temperatures?
153. Name the experiments.
154. What of low temperatures?
155. What are such mixtures called?

CHAPTER IX.

LIGHT.

188. Light is intimately associated with heat, and appears in all solids and liquids that are intensely heated. It can also be separated from the particles of numerous bodies when they enter into new combinations, or are liberated from those of which they may have previously formed a part.

189. Ordinary white light is considered capable of being divided into two parts or pencils, each composed of white light, and these, when separated, are said to constitute *polarized light.* The separation may be effected by certain minerals, or by allowing light to fall upon different substances at a particular angle, when one of these parts or pencils is transmitted, while the other is reflected.

190. Newton considered that white light consisted of seven different species of coloured light combined together, namely, red, orange, yellow, green, blue, indigo, and violet. It is the more general opinion now, however, that white light is composed of three varieties of coloured light, namely, red, yellow, and blue, as all other tints can be produced by them.

191. The influence of light upon chemical action is not so well understood as that of heat; nevertheless, there are numerous instances in which it produces a very marked and striking effect.

192. The *daguerreotype* affords perhaps the most interesting illustration that has yet been pointed out. There, plates of silver, acted on previously by the vapour of iodine, are placed so as to be exposed to the rays of light emanating from any object of which a sketch is de-

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156. What is said of light? white and polarized?
157. What of Newton's theory?
158. What illustration is given of the influence of light on chemical action?

sired. As these rays rest upon the iodine and silver, they so affect the chemical relation and position of the minute particles, that a new arrangement becomes visible after subjecting the plates to the vapour of mercury. The rays of light, therefore, may be said to have traced the outline of the image from which they came as they rested upon the plate. A solution of hyposulphite of soda is then poured over the plate, which precludes farther change.

193. Again, the action of light may be beautifully seen in experimenting with *photogenic* paper. This paper may be prepared by moistening common writing paper with a very weak solution of nitrate of silver, or of bichromate of potassa, excluding it very carefully from the light except when it is in use. On exposing it to the sun, or to the bright light of day, the paper is darkened, and if any part shall have been covered by a leaf, a flower, or any other object, the portion of paper below it remains unchanged, presenting the outline required, while all other parts are darkened. By washing the paper subsequently with water, a solution of hyposulphite of soda, or some other chemical preparation, according to the nature of the material used, no farther change can ensue, and the sketch or outline is at length fixed on the paper.

194. The action of light is also conspicuous in its influence both on plants and animals. Exclusion from the rays of the sun leads to a pallid complexion, indicating a low state of vitality. In the vegetable kingdom, plants placed in a dark situation send out shoots to any opening where light can enter. [By excluding the light from living plants, they are deprived of their green colour, and become white, as is done with celery and some other domestic vegetables.]

195. Clothing of different colours has long been noticed to attract odorous matters with different degrees of force.

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159. Describe the daguerreotype.
160. What of photogenic paper?
161. What are the effects of light upon plants and animals?

The darker the tint the greater the power of attraction, and the longer is the odorous matter retained.

196. On the human frame the precise nature of the action of light has hitherto engaged comparatively little attention; but its effects are admitted to be of great importance, however difficult it may be to trace its mode of operation; and if, in the daguerreotype, it is observed to affect so greatly the particles of dead matter taken from the mineral kingdom, it may be presumed to exert a still more important influence on the body, where the vitality of the materials renders them much more amenable to the influence of external agents.

CHAPTER X.

ELECTRICITY.

197. All bodies present a very peculiar series of properties when placed under particular circumstances, and these have generally been ascribed to the presence of a very subtle fluid, which has been termed *electricity* or the *electric fluid.* Various opinions are entertained as to the nature of this fluid, but nothing precise is known, except many of the effects it can produce on matter. Thunder and lightning are produced by the movements of electricity, such as may be experimented with on the small scale in using the common electrical machine.

198. Electricity, like heat, is in itself invisible, though often accompanied both by heat and light. It exists in all kinds of matter, and does not present, under ordinary circumstances, any manifest indications of its presence. But when any body acquires a larger proportional share than surrounding objects, whatever may be the cause, immediately electricity begins to pass from it to the others; this change going on till any excess is divided between

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162. Define electricity.

them, and an equilibrium established. During this interchange, various phenomena may be observed, more particularly new powers of attraction or repulsion in the substances used, which at the moment are capable of attracting or repelling such matters as may be placed near them, if they are not too heavy. On the small scale, a spark is generally seen at the same time ; on the large scale, in the phenomena of nature, the electric power either is or causes lightning as it passes from the clouds to the earth, from the earth to the clouds, or from one cloud to another. A very intimate connection has also been discovered to subsist between electricity and magnetism ; magnetism can indeed be produced in iron by electrical operations, and magnetic instruments are equally capable of producing an electric spark.

199. Bodies having more than their usual share of electricity, are said to be *positively electrified ;* those that have less, are said to be *negatively electrified.* [For these terms, and the prevalent theory of electricity as well as its chief practical uses, the world is indebted to our illustrious countryman, Dr. Franklin.]

200. *Electric conductors* are bodies through which electricity is conveyed with comparative facility and rapidity ; among these, metallic substances are the most powerful, and through them, notwithstanding the solidity of their texture, it appears to move with the rapidity of lightning. Charcoal, acids, water containing salts in solution, and most animal substances, come next in order.

201. The *lightning-rod,* so much employed in defending buildings from the injurious effects of lightning, affords a good illustration of the application of conductors to practical purposes. The pointed extremity of the rod is freely exposed above the highest part of the building, as is seen in the accompanying figure, and any of the lightning communicated to it, is conveyed away by the metallic rod which is led into the ground below. This rod ought not to terminate in a dry non-conducting body, but

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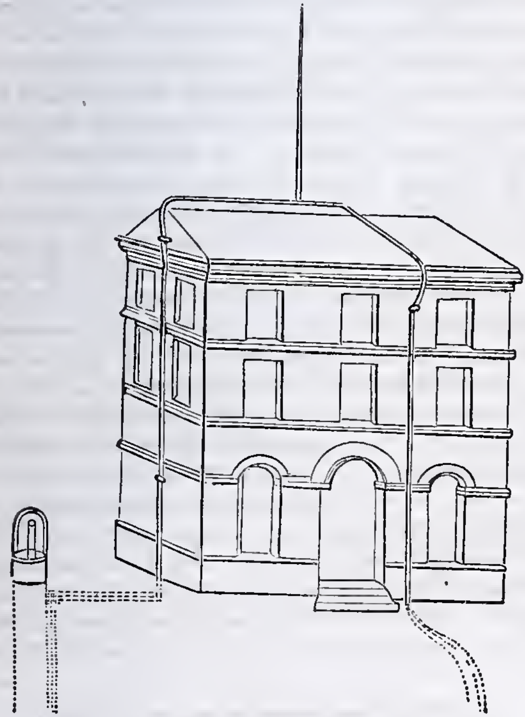
163. What illustrations are cited of the character of electricity ?
164. What two kinds ?
165. Name electric conductors, and illustrate their use.

be conveyed if possible to moist earth or to a well, so that the electricity may be at once discharged into a good conducting medium.

202. In ships, the metallic conductors are usually fixed to the mast-head, and continued down to the copper sheathing in contact with the water, where they terminate.

203. *Non-conductors* are bodies which have comparatively so very feeble a conducting power, that they resist the movement of electricity through their particles, or at least only transmit it with such extreme slowness, that they are familiarly employed to prevent its transmission. Glass, sulphur, resins, dry air, wood, paper, hair, silk, and feathers, are all non-conductors.

Fig. 15.



166. What are non-conductors?

204. The electric *circuit* is the course that electricity takes in passing from one body to another. It is said to be *broken*, or *interrupted*, when the progress of the electricity is arrested or retarded by separating at any point the conducting materials through which it passes, or by interposing any non-conductor between their extremities where the continuity is broken.

205. A body is said to be *insulated* when it is placed on a non-conductor, so that it can neither give electricity with facility to external objects, nor receive it from them.

206. When any body electrically excited is opposed to another in its natural state, the latter assumes an electric condition, exactly opposite to that of the first to which it is opposed.

207. Changes of this kind, effected merely by proximity to an excited body, are called cases of the *induction of electricity*, and the electricity is said to be *induced*. Hence a body, presenting no electrical phenomena, and without any change in the amount of electricity in it, may, in a moment, by a mere change in the distribution of the electricity it contains, caused by the approximation of any body electrically excited, have the arrangement of the electricity in it so altered as to become positively electrical at one extremity, and negatively electrical at the other.

208. In the common electrical machine, electricity is developed by the friction of a hair-cushion covered with an amalgam, [ordinarily made by mixing quicksilver and tinfoil.] which affects the air chemically, as the cushion presses upon a glass cylinder or plate which is made to revolve rapidly. The electricity becomes accumulated in the glass; small and pointed metallic wires attract it and convey it from the revolving glass to a large metallic vessel, *insulated* by being placed on a non-conductor. Were it placed on a conductor, the electricity would be restored to the ground as fast as it might be transmitted to the prime conductor. The hair-cushion must be connected with the ground by a good conductor, that fresh electricity may be

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167. Define *circuit*, when *broken*, or *interrupted*.
168. Define *insulation* and *induction*.

conveyed to it from the earth, as fast as it is withdrawn. Electricity is taken from the prime conductor by approaching to it the body to which it is to be applied.

209. The *Leyden jar*, named from *Leyden*, where it was invented, consists of a jar in which electricity can be accumulated in larger quantity than in the prime conductor. It is coated with tin-foil externally and internally, except towards the upper part. A rod terminating with a ball passes through the upper part, the lower part of the rod being connected with the interior coating by a chain. When the ball is approached to the prime conductor, electricity accumulates in the interior coating of the jar, and this causes electricity to be repelled by induction from the exterior coating. There is, therefore, a great difference established between the electricity of the interior coating, which has more than its usual share, and that of the exterior coating, which has less. The uncoated glass prevents any freedom of communication between them. If a metallic communication be now established between the ball and the external coating, electricity is conveyed rapidly through it to the external surface, and an equilibrium is restored. Any materials subjected to the influence of the electricity of the jar, must be made to form part of the circuit through which it passes.

210. Rub a large stick of sealing-wax briskly with a silk handkerchief; electricity is produced, and light substances, as a feather or a small piece of paper, are attracted by the wax. If the experiment be performed in a dark room, small sparks of electricity may be observed on approaching the finger to the wax.

211. Repeat this experiment, using a stout glass tube instead of the sealing-wax.

212. For ordinary chemical purposes, electricity is developed more conveniently by galvanic arrangements than by the electrical machine. In these the mutual action of different particles of matter brought into play, so

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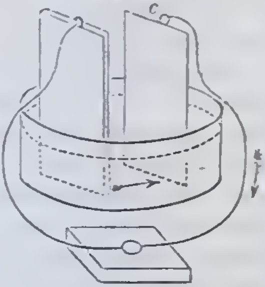
169. Describe the common machine.
170. What of the Leyden jar?
171. Name the experiments here cited.

as to produce chemical changes, is accompanied by the development of a large quantity of electricity.

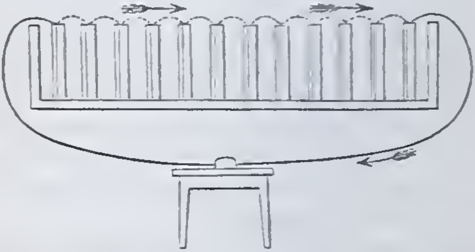
Fig 16.



213. Fig. 16 represents one of the most simple arrangements adopted for this purpose. A plate of zinc and a plate of copper are immersed in an acid liquid capable of affecting one of them; the electricity passes from the zinc to the copper through the liquid; the circuit is established by wires connecting these two plates externally. Any matter to be affected by the electricity must be placed between their extremities, as is represented in the figure.

214. Fig. 17 shows a section of a galvanic trough, in which the united action of any number of pairs of plates may be obtained.

Fig. 17.



215. Fig. 18 shows part of a still more complicated arrangement, such as is used where the united action of a number of troughs is required, all of which act in the same manner as if they had been formed into one trough and properly connected by metallic wires. One extremity, *a*, is represented in connection with a metallic plate, held below one of the metallic leaves *d*, *e*, *f*, *g*. These are placed upon a metallic rod resting on a non-conducting glass support, and attached by *b* to the other extremity of the troughs. If the plate, *c*, be applied successively to each of the metallic leaves, they are dissipated in vapour

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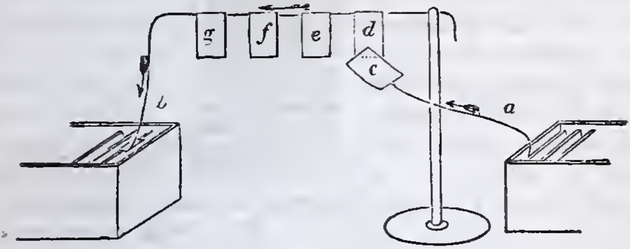
172. How is galvanism produced?

with the evolution of much heat and light. Very thin

Fig. 18.



leaves of gold, silver, copper, and tin, should be used for this purpose. When a number of troughs are connected together, and used simultaneously, the apparatus is termed a *galvanic battery*.

216. In any galvanic arrangement, whether one or many troughs be used, the zinc and copper plates, which are arranged so as to compose the cells, must be placed in one unvarying order, the zinc and copper succeeding each other alternately throughout the whole series. A pair of zinc and copper plates are usually soldered together, the cells being formed by the zinc plate of one pair and the copper plate of another.

217. The cells are usually charged with acids diluted with from ten to fifty parts of water. The greater the intensity of action required, the stronger ought the acid to be. In some batteries, as in that used by Mr. Grove, where a complicated but very effective action is maintained, concentrated acids are employed.

218. On a smaller scale, a very simple arrangement, usually termed the galvanic pile, may be made in the following manner:—Procure twelve plates of copper and twelve plates of zinc, place them in the order represented in fig. 19, with a piece of cloth between each pair, the upper and lower plates having copper wires soldered to them, tipped at the extremity with small wires of platinum. The plates need not be more than two or three inches in diameter, and the cloth must be moistened with

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173. Describe trough, battery, and pile.

a liquid composed of 1 part, by measure, of sulphuric acid, 2 of nitric acid, and 60 of water. The whole of the apparatus may be placed in a small plate or basin. Sometimes each zinc plate is soldered to a copper plate; they can be arranged more conveniently in this way than when separate. With this apparatus the following experiments may be performed.

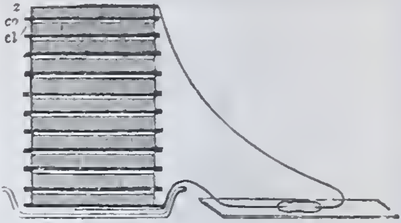

Fig. 19.

219. Place any of the substances mentioned in the succeeding paragraphs, in solution upon a small slip of glass or paper; a drop of the solution will be sufficient. The platinum extremities of the two wires must be dipped into the solution, but not so as to touch each other. The electricity is developed as the acid fluid in the cloth acts upon the zinc, accumulating in one of the wires and passing to the other, the materials in the solution being affected as it passes through and decomposes them.

Materials used.	Products.
1. Sulphate of soda, composed of sulphuric acid and soda, resting on cabbage-paper.	1. The acid accumulates at one wire, and reddens the paper: the alkali at the other, and turns it green.
2. Iodide of potassium, composed of iodine and potassium, mixed with a little starch.	2. The iodine is immediately separated, and forms a blue compound with the starch.
3 Acetate of lead, (common sugar of lead.)	3. Metallic lead is deposited in small crystals.
4 Sulphate of copper.	4. Metallic copper is deposited in the same manner as the lead.
5. Hydrochlorate of tin.	5. Metallic tin is deposited in crystals.*

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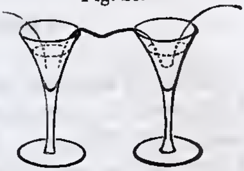
* The *electrotype* is a process where, by arrangements similar to those by which the preceding metals are deposited from their solutions, a metal is made to fall upon any mould, and take the impression of any type, seal, or other figure, which may be required.

220. Put a teaspoonful of sulphate of soda into a cup, and dissolve it in hot water; pour a little cabbage-blue (see Colouring Matter) into the solution, and put a portion into two glasses, connecting them, as represented in fig. 20, by a piece of linen or cotton cloth, previously moistened in the same solution. On putting one of the wires into each glass, the acid accumulates in one, turning the blue to a red, and the alkali in the other rendering it green. If the wires be now reversed, the acid accumulates eventually in the glass where the alkali appeared, while the alkali passes to the glass where the acid was.

Fig. 20.



221. Moisten the fingers with the diluted acid used for the cloth, and hold one wire in each hand; the electricity is felt feebly as it enters the fingers, and passes through the body from one wire to another. With a large apparatus, the most violent convulsive movements, and even death, may be produced.

222. Electricity passes readily through metals and charcoal, and is attracted by all pointed objects in great quantity. Hence, in a thunder-storm, all elevated situations and metallic bodies should be avoided; it is dangerous also to be near trees, as the electricity frequently passes down by them to the earth. The safest place in a thunder-storm is the middle of an open field, at a distance from all high objects; or at home, in the middle of a room, away from the walls, the chimney, and the window.

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174. What experiments are cited?
175. Define an electrotype.
176. What useful hints are given here?

CHAPTER XI.

WATER AND ITS ELEMENTS.

223. Water, or oxide of hydrogen, is composed of hydrogen 1 + oxygen 8; equivalent 9. W. of 1 cubic inch, 252·458 grs. For the action of heat upon it, see Liquefaction and Vaporization.

224. Pure water is transparent, colourless, tasteless, and inodorous, and leaves no residuum when evaporated to dryness. Its compounds are termed *hydrates*, or *aqueous combinations*. It dissolves numerous vegetable, animal, and mineral substances; and is decomposed in many cases of chemical action, affording oxygen or hydrogen to the substances which affect it. It also absorbs or condenses many gases, most of which are expelled on boiling.

225. As a chemical agent, there are few bodies of greater importance either in the great operations of nature or in the processes of art. In the ocean, it not only affords the medium of life and activity to one portion of the animated creation, but appears also to have been an agent by which vast changes have been effected, and are still carried on at the surface of the globe, reducing in particular great and massive rocks to a minute state of division, and preparing them so as to form that soil which is so essential for the productions of the vegetable world, and equally necessary, from the products which it affords, in sustaining animal life. Its power of solution is very remarkable, and many of the rocks or strata deposited from the ocean appear to have in some cases subsided, after having been mechanically suspended in water, while in others they have been separated by a species of deposition or crystallization, such as may be induced artificially on

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177. What is the composition of water?
178. The name of its combinations?
179. What wonderful effects are ascribed to water?

the small scale in numerous chemical processes to which water is constantly subjected. Again, from the immense and extended surface of the ocean, part of the water is continually passing into a state of vapour, when it is separated from the various materials with which it is associated in solution; and being thus distributed over the surface of the land by the movements it is subjected to as it travels invisibly in the air, or in the form of a cloud, is ultimately deposited, free from impurities, at the surface of the globe, nourishing animal and vegetable life as it falls in the rain or the dew-drop, while it also acts chemically upon numerous ingredients that are observed in the mineral kingdom.

226. *Pure water*, for chemical purposes, is prepared by distillation (see 146), as it is nowhere obtained absolutely pure in nature; the impurities remain in the retort or still. Rain and snow-water are the purest natural waters; even these must be boiled to expel air, when water is required absolutely pure.

227. For ordinary purposes, water may often be purified to a certain extent without distillation, by filtering it through beds of gravel and sand, and still more effectually by the action of animal charcoal, which absorbs or destroys numerous offensive matters that are often associated with it. Ordinary charcoal has a similar effect, but is much less powerful than animal charcoal, probably from the absence of a minute quantity of lime which the other is known to contain along with various salts.

228. Some varieties of water, as the water of the Thames, undergo considerable changes when kept for some time in casks at sea or in other situations, the animal and vegetable matter it retains in solution, after impurities merely mechanically suspended have been removed by filtration, producing a kind of fermentation when they are in a great measure decomposed; the water then becomes fit for use. Iron tanks have been much used of late for

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180. What of pure water?
181. What artificial and spontaneous changes in water?
182. What is said of iron and of leaden vessels?

holding water on board ships, and might be adopted with advantage in other situations. In them good water may be preserved for any length of time, if the air be excluded. Leaden vessels may be used without injury for holding some varieties of water, when the saline matter in the water forms an insoluble compound with the superficial particles of the lead, adhering to it closely, and protecting it from further injury. But other varieties of water it is very dangerous to place in leaden cisterns, as they corrode the lead, and suspend a portion of it in a minute state of division, becoming then highly poisonous; the suspended lead is considered in general to become a carbonate, acquiring carbonic acid and oxygen from such waters; and in this condition, being in an extremely minute state of division, it is suspended with comparative facility. No water ought to be kept in leaden cisterns for ordinary purposes, without previously ascertaining its chemical qualities and its disposition to corrode the lead. Whole villages have suffered severely from the effects of lead, where pipes of this material have been incautiously substituted for others made of earthenware or wood.

229. *Spring water* is not so insipid and tasteless as distilled water, containing portions of air, as well as saline or earthy matter which it may have dissolved while flowing in contact with various rocks and minerals. *River water* is similar to spring water, but oftener loaded with impurities. *Well water* is still less pure. Water is said to be *hard* when it is so loaded with foreign matter that it decomposes soap, producing a curdy precipitate, so that it is unfit for washing, or for dissolving many substances in daily use.

230. *Mineral waters* include all those which are so charged with foreign matter as to acquire peculiar properties. The following are the principal varieties of mineral waters, and their properties should be studied along with the properties of those substances in which they abound.

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83. What of various forms of water?
84. Describe mineral waters.

These are printed in italics; and by referring to them as they are described in succeeding chapters, the tests by which they are distinguished will be seen.

I. Acidulous mineral water abounds in *carbonic acid.*

II. Sulphureous mineral water contains *sulphureted hydrogen.*

III. Saline mineral water contains principally *soda, lime,* or *magnesia,* united generally with *sulphuric* and *hydrochloric acids.*

IV. Chalybeate mineral waters contain *iron,* united with *sulphuric* or *carbonic acid.*

231. To acquire at once a general knowledge of the properties of any water, the following experiments may be tried:—

I. Evaporate a drop on a flat slip of glass, holding it before the fire, or above a small lamp or candle. Small thin rings appear where the water rested, if it contained only a minute quantity of foreign matter; but a crust is seen, if it be loaded with saline or earthy matter; the crust has a brownish-yellow tint if iron be present. All ordinary varieties of water containing variable quantities of saline or earthy compounds in solutions, a crust, or sediment, is always left when large quantities are evaporated. In steam-engine boilers this is particularly observed, the crust requiring to be removed periodically, otherwise the deposition is so great that the communication of heat is altogether arrested through the thick mass of earthy matter that rests upon the bottom of the boiler.

II. Pour some of the water into a wine glass, and add a solution of litmus; it is reddened if any acid matter be present.

III. Mix another portion with a little soap; a curdy substance appears if it abound in earthy matter. [If a drop of the solution of nitrate of silver be added to water containing common salt, it will be instantly precipitated, and is thence used as a test for detecting salt in pump water.]

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185. Name the experiments cited.
186. What are the effects of boiling water?

232. Many waters may be purified to a great extent merely by boiling, when carbonic acid and sulphuretted hydrogen gases are at once expelled, if not retained in solution by soluble compounds with which they may be combined. In waters abounding in lime and iron dissolved by carbonic acid, the most marked effect is produced by boiling, much of the carbonic acid being at once expelled, while the lime and iron are separated in combination with part of the acid in the solid form, the water being left altogether, or at least comparatively, pure.

OXYGEN.

233. This element is a gas. It is 16 times heavier than hydrogen, and forms more than one-half of the globe, constituting 8 tons in every 36 of air, 8 in every 9 of water, nearly a half of the more abundant earths, silica and alumina, besides being found in almost all vegetable and animal matters. It received the name of oxygen from Greek words, signifying to produce a sour substance, many of its compounds being acid.

234. *Oxides* are compounds of oxygen which are not acid. *Oxidation* signifies the union of any body with oxygen. Substances which communicate oxygen with facility to other matters, are called *oxidating agents;* the principal are air, water, and acids and salts containing oxygen. *Deoxidating agents* include those substances which are powerful in removing oxygen, as carbon, hydrogen, phosphorus, iron, and many other metals.

235. Oxygen is particularly distinguished by its power of supporting combustion; all inflammable substances burn brilliantly in it. It is not known, however, in what manner heat and light are evolved, as the particles of the combustible body affect the particles of the oxygen, and combine with them. Some bodies are warm enough to

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187. Define oxygen and its compounds.
188. What is the prominent property of oxygen named?
189. What of slow and spontaneous combustion?
190. What experiment is cited?
191. How is oxygen prepared?
192. How prepared without a furnace?

take fire at natural temperatures, and are never, accordingly, observed under ordinary circumstances at the surface of the earth; but in others a very various degree of heat is required to produce actual combustion. Phosphorus takes fire at a temperature of 100 degrees, sulphur at 300 degrees, and carbon at various temperatures between 280 degrees and the high temperature of a white heat, according as it is used in the form of a light and porous charcoal, of a soft or hard coke, or of the diamond, in which the close aggregation of the particles renders it very difficult of combustion.

236. Besides that rapid combustion which is familiarly observed in a common fire, numerous inflammable substances, more especially phosphorus, a number of oils, charcoal, coals, and other substances, which can be reduced to a minute state of division, are prone to act slowly upon the oxygen of the air. This is more particularly observed if the materials used be accumulated in very considerable quantities, so as to expose an extensive surface to it by being arranged in heaps, or spread, if fluid (as when oils are used), upon cotton, tow, or saw-dust, so as to give a similar extensive surface, upon which the air can act in the various interstices, without allowing it to be carried too rapidly away from the different particles upon which it may impinge. The action of the air and the inflammable matter under such circumstances, is usually referred to under the title of *slow combustion;* and all cases of this kind ought to be very carefully studied, as the accumulation of heat from this cause frequently increases to such an extent, that the materials ultimately burst into an active and vivid combustion. Numerous fires, both on board ship and on shore, particularly in manufactories where oil, tow, cotton, and machinery are used, have been traced to this cause. Cases have been recorded where the materials have passed into a state of active combustion in a few hours; instances have also been authenticated in which nearly a year elapsed before the fire appeared.

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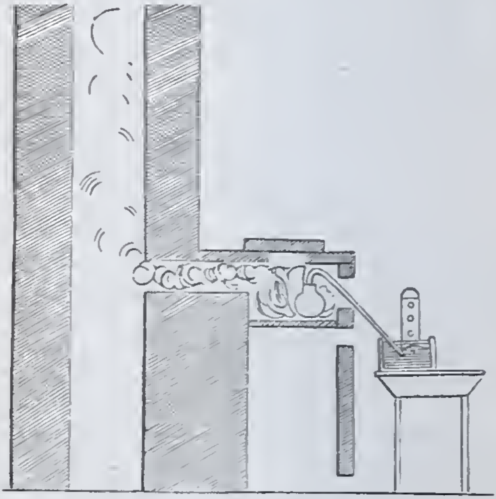
193. Describe the pneumatic trough.
194. Name the experiments and apparatus.

237. Introduce a wooden match, red hot at the end, into a jar of oxygen, or a suspended candle (fig 21) with the wick red; it burns brilliantly, and the flame is rekindled. In all cases where ordinary inflammable matter burns, it acts upon the oxygen which is contained in the air, and combines with it. The inflammable matter is not lost or destroyed, but often becomes invisible like the air itself, as it forms gaseous compounds.

Fig. 21

238. Preparation.—Binoxide of manganese is heated to redness in an iron bottle placed in an open fire, or resting in a furnace, as in the annexed cut, fig. 22. The bottle should be large enough to contain several ounces of the binoxide; and the oxygen which is not required for immediate use should be collected in beer bottles previously filled with water, and employed afterwards as it may be required. The bottles should be corked under water, the corks being afterwards covered with lard, and a piece of cloth tied round them.

Fig. 22.



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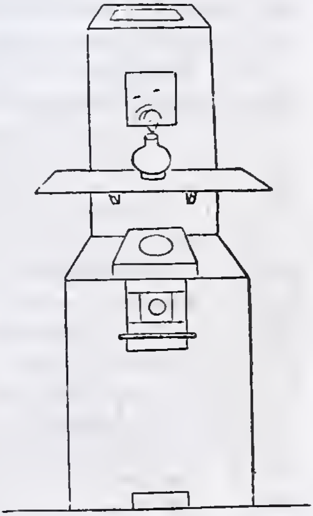
195. What is the character of hydrogen?
196. How prepared? experiments.

239. When the binoxide is contaminated with carbonate of lime, or other carbonates, carbonic acid gas is evolved along with the oxygen. This gas is very different from oxygen, and much impairs its value. By using water in the pneumatic trough, to which lime has been added, the carbonic acid is absorbed, and retained in combination with the lime.

240. The furnace represented here is of a form extremely convenient for numerous operations; and, where the vent is exposed on every side, other furnaces may be placed around it. The area for the fuel may be made from 9 inches to a foot square, and the small chimney from 5 to 6 inches in diameter. A front view is given in fig. 23, to show the manner in which the bricks are arranged in small pieces, so as to be taken out and adjusted according to the experiment to be performed. The chimney works well if it be 9 or 10 inches square, and from 10 to 20 feet high. A shelf is placed before and below an aperture in the chimney; and when it is required to carry off fumes from any mixture, it is placed in the situation occupied by the flask, the plug being removed from the aperture, which is at other times closed.

Fig. 23.



241. When the binoxide is heated in the furnace, eighty-eight grains give 8 of oxygen, and every grain may be considered as equal to three cubic inches of gas.

242. Where there is no opportunity of operating with a furnace, 1000 grains of the binoxide in fine powder may be mixed in a retort with an equal weight (about $1\frac{1}{4}$ ounces by measure) of aqueous sulphuric acid; in this case every 44 grains give 8 of oxygen;

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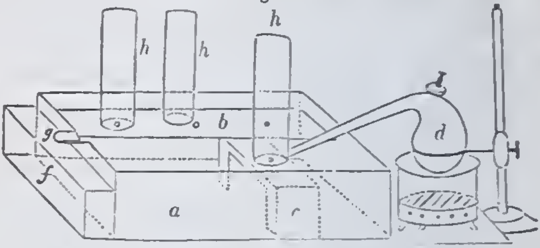
197. What instrument is employed in burning this gas with oxygen, and its uses?

but this process is not so well adapted for preparing a large quantity of oxygen. The retort must be heated by a chauffer or lamp, and the heat withdrawn whenever the gas ceases to escape, otherwise the water might pass into the retort and break it, being forced up by the pressure of the air as the gas still in the retort cools and contracts.

Fig. 24.



243. The trough *a* (fig. 24) is usually made of wood or tinned iron, about 24 inches long, 12 broad, and 8 deep. The shelf *b* and moveable stool *c* may be made 7 inches high. The pneumatic jars *h h h* being filled with water; gas is prepared from the retort *d*; the spout *g* discharges any excess of water from the jars as they are filled with gas, the water passing into the small trough *f*.

244. Zinc trays (fig. 25) or small plates are placed below the jars of gas under water, when they are to be removed from the trough, and used for experiments. The jars or bottles used for collecting the gas must always be filled with water to expel air, before any gas is collected.

Fig. 25.

245. Jars of this form (fig. 26) are often used to transfer oxygen or other gases to a bag or bladder, adjusted mutually to each other by movable connectors. The jars being filled with gas, and then depressed in water, the gas is forced into the empty bag, which is slowly distended. The bag having been withdrawn, a nozzle is fitted to it (fig. 27), by which the gas can be directed upon any object when it is compressed.

Fig. 26.

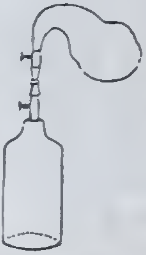
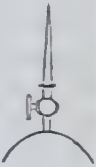


Fig. 27.



HYDROGEN.

246. Hydrogen is a gas, and the lightest of all known substances; it is nearly 14½ times lighter than air; 100 c. i. weigh only 2 grains and a fraction. Its name is derived from two Greek words signifying to produce water, as that fluid is formed when 1 part of hydrogen unites with 8 of oxygen.

247. Hydrogen constitutes 1-9th of the water of the globe, and is also found in almost all animal and vegetable substances.

248. PREPARATION.—Put 500 grains of zinc in fragments into a common beer-bottle; pour upon them 3 ounces of water, and add 5 drachms of aqueous sulphuric acid. The acid, the oxygen of part of the water, and the metal, combine, producing sulphate of zinc; the hydrogen is disengaged, and may be collected at the pneumatic trough in jars; a cork with a bent tube is adapted to the neck of the bottle (fig. 28) to convey the gas to the jars, which can be arranged as in fig. 24.

249. Zinc is procured in fragments by melting it, and pouring it from a height into water. Iron-filings may be substituted for zinc; the acid should then be added slowly, and an apparatus of the form shown in fig. 29 is convenient, as it may be introduced by the long tube in small quantities at a time, to prevent the action going on too briskly. Small nails may be used instead of the filings.

Fig. 28.

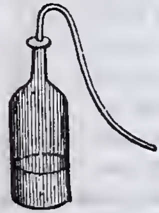


Fig. 29.

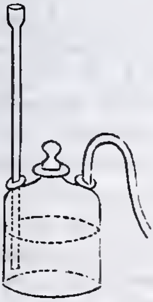
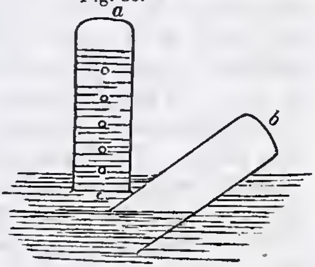


Fig. 30.



250. Invert a jar with hydrogen, after covering the mouth with a tray or cover, and apply a lighted match as the cover is taken off; the hydrogen burns rapidly, uniting with the oxygen of the air, and producing water.

251. Inflame hydrogen gas in another jar, keeping the mouth downwards; the light hydrogen mixes this time more slowly with the air, and takes a longer time to burn.

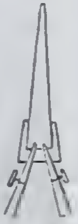
252. Take any small jar or phial, fill it with oxygen, and then introduce the oxygen into a larger and very strong jar; fill the small jar twice with hydrogen, and mix it with the oxygen in the larger jar. Invert the mixture and apply a lighted match; an immediate detonation ensues, and water is formed.

253. Practise transferring gases from one jar to another under water, holding them as in fig. 30.

254. Transfer hydrogen into a bag with a small nozzle (fig. 27); press it so as to direct a stream upon a small portion of spongy platinum less than a pea, and supported loosely in a small coil of platinum wire; the air, or oxygen, acting on the platinum at the same instant with the hydrogen, the metal soon becomes red hot, and the hydrogen is inflamed.

255. If two bags be taken, one with oxygen, the other with hydrogen, and a stream of gas be pressed out from both at the same instant, so that they unite and produce one jet of flame, an intense degree of heat is excited; this apparatus is usually termed the *oxyhydrogen blowpipe.* Iron-wire held in the flame quickly burns; small fragments of copper, zinc, antimony, lead, and tin, burn with great rapidity, if supported on charcoal; small pieces should be taken, less than a pea. Lime, tobacco pipe-clay, and other earthy substances, become intensely luminous in this flame. The hydrogen requires only half its bulk of oxygen to be mixed with it; and the gases are apt to explode if they be mixed in one vessel, unless the tubes be arranged in a particular manner to prevent the flame from returning. The figure shows the manner in which the nozzles from the bags are connected in another nozzle, at the extremity of which

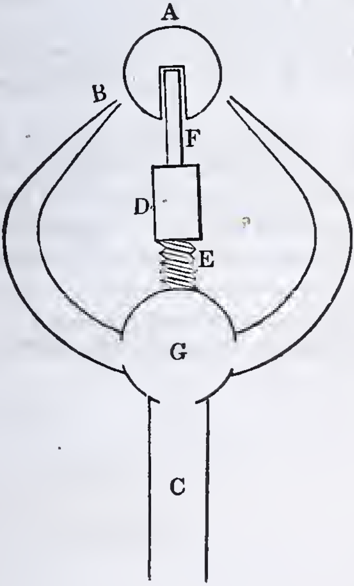
Fig. 31.



the flame is produced. These nozzles are usually made of brass, and about 1-50th of an inch in diameter at the extremity, or rather less.

256. An excess of hydrogen should always be used, as it renders the small portion of the mixture within this nozzle much less liable to explosion; as a farther security against the very trifling explosion that might be produced by any return of the flame into this nozzle, containing the mixed gases, it is often filled with numerous layers of wire gauze.

Fig. 32.



257. In experiments on a larger scale, gasometers or reservoirs for the separate gases are employed, and Dr. Hare [of Philadelphia, the eminent professor of Chemistry in the University of Pennsylvania,] who introduced the use of the oxyhydrogen blowpipe, has for some years used

it for melting platinum, a metal that is not conveniently fused in furnaces worked with common fuel.

258. When a very intense light is required, so that it shall be concentrated within a very limited space, it is produced in general by directing a number of small jets of flame from the oxyhydrogen blowpipe upon a ball of lime, supported in the manner represented in the preceding figure. So intense is the light evolved, that it has been seen in a clear night at the distance of ninety-six miles. A, the lime-ball ; B, one of a number of nozzles proceding from the centre G ; C, the stem of the blowpipe containing the mixed gases ; D, the support for the ball, terminating in a platinum rod F, and moving upon a screw E, so that it can be adjusted to a proper height.

259. Symbols of processes described, with a translation :—

$\mathrm{H}\,\&\,\mathrm{O} = \cdot\mathrm{H}$. Hydrogen and oxygen produce water.

$\vdots\mathrm{S}\,\&\,\cdot\mathrm{H}\,\&\,\mathrm{Z} = \vdots\mathrm{S}\cdot\dot{\mathrm{Z}}\,\&\,\mathrm{H}$. Sulphuric acid, water and zinc, produce sulphate of zinc and hydrogen.

$\vdots\mathrm{S}\,\&\,\cdot\mathrm{H}\,\&\,\mathrm{Fe} = \vdots\mathrm{S}\cdot\mathrm{Fe}\,\&\,\mathrm{H}$. Sulphuric acid and water, and iron, produce sulphate of iron and hydrogen.

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198. Who introduced this instrument ?
199. How is the Drummond light made ?

CHAPTER XII.

AIR AND ITS ELEMENTS.

260. Air is not an element, but a compound of two gases, oxygen and nitrogen, and its chemical properties depend principally upon the oxygen it contains. The oxygen combines with inflammable matter during combustion, it acts on the blood in the lungs when animals respire, and its influence may be traced in numerous operations continually going on at the surface of the earth. When the oxygen of the air is consumed, inflammable substances do not burn in it, and animals introduced into it immediately die. Hence the great importance of removing air vitiated by combustion or respiration, and introducing into every apartment fresh air from a pure source. Much of the oppression and headache of which many persons at times complain, either arises entirely, or at least is much aggravated, by breathing for a great length of time in an atmosphere vitiated by a crowded assembly, or imperfect ventilation.*

261. Minute quantities of moisture and carbonic acid are found in air in every part of the globe, which have an important influence in numerous changes at the surface of the earth; and though large quantities of oxygen must be continually consumed, still the composition of the air does not vary, oxygen being again restored to it, principally, it is believed, by the action of the leaves of plants during sunshine.

Fig. 33.

262. Put a lighted candle, about two or three inches long, upon the shelf of the pneumatic trough, (fig. 21.) supporting it above the water on any small metallic stand (fig. 33). Place over it a glass jar eight or ten inches long, allowing it to rest upon

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* For illustrations of Ventilation, see Carbon, Fire-places, and Furnaces.

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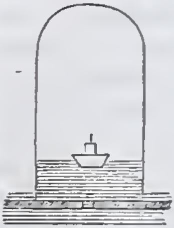
200. What is the composition of the air?
201. Upon which element does its utility depend?
202. What illustrations of its importance are cited?
203. How is the oxygen in the air replenished?

the shelf. The air in the jar is at first expanded by the heat, and a little escapes; the candle soon begins to burn more dimly as the inflammable matter it contains consumes the oxygen, and in a short time it is extinguished. Water is now forced up by the pressure of the external air to supply the place of the air expelled at first, and also of part of that which is consumed, a portion of the product being condensed by the water.

263. Repeat this experiment, using a candle supported on a cork, so as to float upon the surface of the water, as in the annexed figure.

Fig. 24.



264. Again repeat this experiment, using nothing. however, but the candle and the glass jar, previously dried with great care; the candle being put on a table, and the jar placed over it.

265. In all these cases a large portion of the oxygen of the air is consumed, uniting with the hydrogen, and also with the carbon, which form the principal ingredients in wax, oil, and tallow. The water that appears in innumerable small points or drops upon the sides of the dry jar, is formed by the union of the hydrogen of the candle with the oxygen of the air; the carbonic acid gas is formed as the carbon unites with oxygen, and this may be easily detected by the addition of lime-water, which is immediately rendered turbid by the carbonic acid, if a few ounces be agitated with it in the jar.

266. In studying the action of air upon different chemicals, and still more especially in viewing its effects upon the human frame, the following memoranda will be found useful:—

267. Air, at a temperature varying from 60 to 65 degrees, is found to be most congenial to the greater number of constitutions in this country, if it move so gently that fresh quantities are continually conveyed to the system without any sensible impetus, or at least without produc-

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264. What experiment is given?
265 Explain the experiments.

ing any offensive current. Different constitutions vary much as to the temperature that is most suitable for them. A difference of 24 degrees is observed in extreme cases as to the temperature preferred by different persons; and, even in the same individual, a very great difference may often be seen as to the temperature that is preferred, according to the state of the constitution at different times. As age advances, and the bodily strength diminishes, a temperature from 63 to 68 degrees is found most agreeable.

268. Air, at a high temperature, provided that it be below the temperature of the body, may produce the same amount of cooling power as air at a lower temperature, if it be made to move more rapidly, so that a larger quantity of it shall be brought in contact with the system in a given time. Hence, air at a given temperature may feel agreeably warm or very cold, according to the rapidity with which it moves upon the person. Temperature, therefore, considered independently of the velocity or slowness of movement in the air, is no guide as to the precise manner in which it is likely to affect the feelings. Air may be perfectly pure in respect to its proportion of oxygen and nitrogen, but may be vitiated by the presence of moisture in unusual quantity, when it arrests insensible transpiration, and affects seriously the functions of the skin.

269. On the other hand, air may be so free from moisture, that it may withdraw moisture rapidly from the system, and produce injurious effects by its extreme dryness. Air is more largely charged with moisture in summer than in winter, but has less tendency to deposit that moisture, in consequence of the high temperature.

270. In winter, though the amount of moisture in the air may be less, it is apt to become more offensive from the facility with which it is separated in a palpable form.

271. In addition to those changes that result from a difference of temperature. air is apt to vary greatly in its influence upon the human frame, according to its electrical condition, which has not hitherto been studied so minutely

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206. What is said of the temperature of the air?
207. What of moisture in the air?

as its importance requires. Further, the following materials may be found in the air in different districts, in very variable proportions, or only in particular localities, according to the nature of the source from which they are evolved.

272. *Carbonic acid;* carbon, the principal ingredient in all animal and vegetable substances, tends ultimately to become carbonic acid gas as they fade and decay, when it is diffused through the air and absorbed by the leaves of plants, or by water which approaches their roots, and again presents it as a source of food in the vegetable kingdom. In a proportion of about 1–1000th part, it is found everywhere in the atmosphere; in old wells and pits it is often so abundant that certain death ensues when any one incautiously visits those in which it is accumulated.

273. *Carbureted hydrogen* is found principally in coal mines, or escaping from strata in which coal, tar, naphtha, and other inflammable substances, abound.

274. *Sulphureted hydrogen* is noticed more particularly in the vicinity of sulphureous waters, and where compounds termed sulphates are left in stagnant water and in contact with animal or vegetable matter.

275. *Sulphurous acid* may also be observed near active volcanoes, copper works, and large cities. In Wales, 80,000 tons of sulphur are annually consumed and discharged, after being dissipated in the form of sulphurous acid, from four works alone in which copper is separated from the ore.

276. *Minute particles* of exceedingly fine *dust* are noticed principally when a tempestuous atmosphere blows upon a sandy desert, or when they are projected from active volcanoes. In some cases the dust has covered the decks of ships at some distance to the depth of half an inch or more, and instances are recorded where it has been deposited in large quantities at a distance of 400 miles from the volcano by which it was discharged.

277. *Salt* is noticed more particularly towards the sea-

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208. What other agencies modify it?
209. Name different materials found in the air.

coast, but has also been found encrusting leaves at a distance of 200 miles from the sea. It is supposed to be derived from the spray of the sea, agitated greatly during a heavy gale of wind.

278. *Malarious matters* are the offensive products that arise from various soils and marshes, and from animal and vegetable matter generally, in a state of decay. Thousands die annually from its injurious influence, but its precise nature is unknown, and probably there are many varieties of malaria, each having peculiar properties. It has been supposed that many minute and invisible animalculæ sometimes produce diseases attributed to malaria, while offensive gases, or, at all events, offensive compounds which are soluble in gases, such as are met with at the surface of the earth, have also been considered to produce these effects. By the action of a high temperature, by the agency of chlorine, of lime-water, and other substances, attempts have been lately made to diminish the virulence of the action of malarious poisons, but until their precise nature shall have been more accurately investigated, it will be impossible to propose specific plans for destroying its influence in each individual case.

279. Numerous substances, as arsenic, copper, hydrochloric acid, and other bodies, may be traced in endless variety in some situations, especially in the vicinity of particular manufactories. Air in large cities, such as London and Manchester, is often largely contaminated with soot. In the worst cases in these places, nearly 400 separate pieces of soot have been observed to fall within a few hours upon a square foot of surface.

280. In most buildings the supply of air is taken too frequently from the most indifferent sources, while the due discharge of the vitiated air is equally uncontrolled. The higher the source from which air is taken, the better is it in general, and the more free from exhalations from drains, &c.; care must be taken not to lead it from the same level as that of chimney tops in the vicinity.

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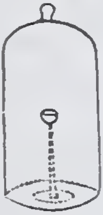
210. What is said of malaria?
211. In what situations is air the purest?

NITROGEN.

281. This gas abounds in the air. forming 4–5ths of its bulk, and is also found in considerable quantity in animal substances, and in salts called nitrates. It is observed only in a few vegetable substances.

282. Put 8 or 10 grains of phosphorus into a tin or copper cup, supported several inches high (fig. 35), and place over it, when inflamed, a jar about the size of a common beer-bottle, operating at the pneumatic trough, as in fig. 24. The phosphorus should never be touched directly with the hand, and must be dried well between folds of blotting-paper before it is used. When the white compound of the phosphorus and oxygen of the included air has combined with the water, nitrogen gas remains, transparent and colourless.

Fig. 35.



283. Transfer it under water to another jar, previously filled with water, holding them in the manner shown in fig. 30; or invert the jar with a cover, keeping in all the water, and introduce a suspended candle (fig. 21) into the gas; it is immediately extinguished. The nitrogen may be contrasted with oxygen in another jar, the candle being extinguished in the one, and rekindled in the other many successive times.

284. Nitrogen neither supports combustion nor respiration. It is disengaged with great facility from numerous compounds, many of which explode violently as it is separated.

NITRIC ACID.

285. The elements of air, united in a different proportion, form nitric acid, one of the most corrosive and powerful acids; diluted with water, it constitutes aquafortis.

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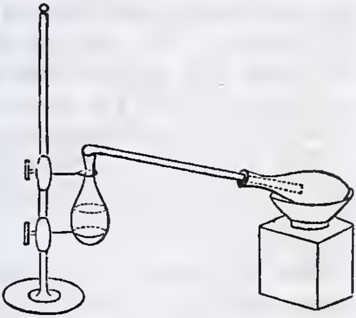
212. Describe nitrogen and its uses.
213 How is it prepared. and what experiments?
214. Wherein does it differ from oxygen?
215. What other compounds is made of the same ingredients as the air?
216. How is nitric acid prepared? experiments.

286. Compounds which have a sour taste, and redden blue vegetable colouring matter, are termed acids, though a few of them are very feeble in these respects.

287. Fill a glass retort about one-third full of a mixture of equal weights of aqueous sulphuric acid and nitrate of potassa (common nitre); heat the mixture with a lamp or chauffer, and collect the vapour that distils over in a receiver, which must be kept cold; if the vapour comes over more rapidly than it can be condensed, the heat must be moderated.

288. A flask with a bent tube fitted to it may be used instead of a retort, being luted to it with a mixture of clay and sand, when the materials have been introduced. (Fig. 36.)

Fig. 36.



289. The process should be continued till a quantity of acid be obtained, at least equal in bulk to the aqueous sulphuric acid employed. Part of the acid is generally decomposed, and a ruddy vapour produced which tinges the acid of various hues; it is called nitrous acid. The sulphuric acid remains in the retort with the potassa of the nitre, and the nitric acid passes into the receiver united with water, which it takes from the aqueous sulphuric acid employed.

290. Add a drop of the acid to water in a beer-glass, coloured with vegetable blue; it is immediately reddened.

291. Cover a tea-spoonful of iron filings in another beer-glass with water, and pour upon them small quantities of acid at a time till a brisk effervescence appears. The iron takes oxygen from the acid, and many gases are disengaged, composed of nitrogen with less oxygen than is found in the acid.

292. Heat two table-spoonfuls of charcoal powder to

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217. Explain the experiments here cited.
218. What peculiarities of nitric acid are named?

redness in a crucible, and pour upon it aqueous nitric acid in a very slender stream: the charcoal burns rapidly, taking oxygen from the acid.

293. Nitric acid is always associated with water as usually procured, and should be kept carefully in stoppled phials, as it is very corrosive, and emits acrid fumes. It is transparent and colourless when there is no nitrous acid present, and if concentrated, a phial that holds 1000 grains of water will contain about 1480 of this acid. It is often contaminated with sulphuric acid or chlorine, which may be detected by solutions of nitrate of baryta and nitrate of silver. The acid should be diluted in a wine-glass, before the tests are applied, with 6 or 8 times its bulk of distilled water. The tests produce no effect in pure acid; sulphuric acid gives a white precipitate with baryta, and chlorine produces the same effect with the silver. The tests must be tried in separate glasses.

294. Evaporate a portion of the nitric acid on a broad slip of glass, or in an evaporating basin, till none is left. If any solid matter remain, it is also to be regarded as an impurity.

295. The other compounds of nitrogen and oxygen are represented in the table, page 39. They are produced when nitric acid or its compounds are decomposed.

296. *Oxide of nitrogen*, vulgarly called nitrous oxide, or exhilarating gas, or intoxicating gas, can be respired for a minute or two without danger; it produces great excitement in general, accompanied by immoderate laughter, and violent muscular action. Its effects pass away very quickly.

297. It is prepared by decomposing nitrate of ammonia, which is resolved into this gas and water on subjecting it to heat in a retort, the water being condensed at the pneumatic trough, while the gas is collected in jars. The diagram, page 39, illustrates the precise nature of the changes that ensue.

298. *Binoxide of nitrogen* is also gaseous, and, when

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219. What other compounds of oxygen and nitrogen?
220. How prepared?

mixed with air or oxygen, produces dense, acrid, ruddy fumes of nitrous acid. It is obtained by the action of copper or mercury on diluted nitric acid, the metal removing part of the oxygen from a portion of the acid, and liberating the gaseous binoxide, while the undecomposed acid combines with the oxidated metals.

299. Nitrous acid generally appears as a ruddy vapour when nitric acid is decomposed, or when the binoxide acts on the air and attracts more oxygen.

CHAPTER XIII.

SULPHUR AND PHOSPHORUS.

300. *Sulphur* is a brittle solid, having a fine straw-yellow colour. It abounds in many volcanic countries, where it is believed to have been separated from its various compounds by the action of heat. It is also prepared artificially by heating compounds in which it is combined with metals. The most important compounds it forms with the preceding elements are sulphurous acid, sulphuric acid, and sulphureted hydrogen.

301. Hold a roll of sulphur over a powerful lamp; it soon falls in pieces, the exterior portion expanding, while the rest is rigid. Sulphur is a bad conductor of heat.

302. Melt sulphur in a Florence flask, and pour it, whenever it is fluid, into water, it immediately becomes hard and brittle.

303. Heat another portion, after melting it, till it becomes thick and viscid; pour it, in a very slender stream, into water; it is now transparent, soft, and elastic, but gradually returns to its usual form.

304. Heat sulphur in a small retort; the vapour con-

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221. Describe sulphur and its sources, and compounds.
222. What experiments are cited?

denses in the neck of the retort, or in a receiver which may be connected with it, in the form of a yellow powder, usually called Flour of Sulphur.

305. Melt sulphur in an earthenware cup, and allow it to cool; it consolidates into a crystalline mass. Observe the crystals as they shoot across the liquid. Dip small pieces of wood into melted sulphur; a portion of it adheres to the wood, and common sulphur matches are formed.

306. Pour melted sulphur upon a glass or other mould made of materials such as are not affected by the heat of the fluid sulphur. It takes a very accurate impression as it cools. Metallic substances are very apt to be discoloured by sulphur, and ought therefore to be avoided.

307. *Sulphurous acid* is formed when sulphur burns in contact with the air or pure oxygen. It is a pungent suffocating gas; water can condense thirty-three times its bulk, acquiring its odour. It becomes liquid when its temperature is reduced to 14 degrees; in this condition it evaporates quickly if exposed to the air, and produces intense cold. When sulphur is burned in oxygen, a very beautiful blue light appears. The same apparatus may be used as in burning phosphorus in air to prepare nitrogen (See 282), or a few fragments of sulphur may be kindled in a copper cup, suspended by a wire (Fig. 37), and introduced into a phial, vase, or flask, filled with oxygen gas.

Fig. 37.

308. Sulphurous acid may be obtained in combination with water, but mixed in general with a little sulphuric acid, by heating 200 grains of mercury with an equal weight of aqueous sulphuric acid in a retort, and condensing the gas that is evolved by water placed in a flask or receiver. The sulphurous acid is formed as the mercury takes a portion of oxygen from part of the sulphuric acid; the rest of the acid combines with the mercury.

309. Sulphurous acid is particularly distinguished by its action on colouring matter. Numerous flowers are

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223. What of sulphurous acid?
224. Its preparation and uses.

blanched when placed in a jar where sulphurous acid is slowly produced. Though the colour may fade and disappear, its basis is not destroyed, as, in many cases at least, it may be restored by the action of acid or alkaline vapours.

310. Sulphurous acid is formed in all ordinary cases not only where pure sulphur is burned, but also where many of its compounds are exposed to the action of heat and air, as in the Welsh copper works already referred to, par. 275, page 94. The 80,000 tons of sulphur mentioned produce 160,000 tons of sulphurous acid gas, and part of the copper is also dissipated at the same time, destroying all vegetation in the vicinity, and even affecting animals with a peculiar disease termed popularly the *copper-smoke lameness.* In various other places, also, where different manufactories are carried on, numerous cases are pointed out where the deleterious action of the sulphurous acid, caused by the burning of the sulphur, has produced the most injurious effects, being equally inimical to animal life and to vegetation.

311. Sulphuric acid is the most important compound of sulphur, and is termed *aqueous sulphuric acid*, in the condition it is usually met with, about 40·1 of acid being combined with 9 of water. It is prepared by mixing sulphurous acid gas, formed by burning sulphur, with nitrous and nitric acid, in a large chamber lined with lead; the sulphurous acid becomes sulphuric acid after decomposing the nitrous or nitric acid, and attracting a portion of oxygen from it and the air. When properly concentrated, it is a dense oily-looking fluid, heavier than water, and is known by the name of oil of vitriol. It is much employed in decomposing compounds containing acids, corrodes animal and vegetable matter, and is intensely acid. It reddens the vegetable blues.

312. Sulphuric acid, associated with other substances, is found abundantly in the mineral kingdom, more especially in combination with lime, soda, and magnesia.

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225. What of its mischievous effects?
226. What is sulphuric acid, and how prepared?
227. Where is it found in nature? examples.

But though a virulent poison, and extremely corrosive of animal and vegetable matter, when concentrated and pure, it loses all these qualities on combination with the substances mentioned, when it produces successively sulphate of lime or plaster of Paris, sulphate of soda or Glauber's salt, and sulphate of magnesia or Epsom salt.

313. Sulphuric acid in solution is detected by adding a solution of lead or of baryta; a white precipitate immediately falls, which is not dissolved on adding diluted nitric acid. In earthy compounds not soluble in water, sulphuric acid is detected by heating them to bright redness in a crucible with powdered charcoal, after mixing them with a little pitch or oil, when a compound is obtained which produces a sulphureous odour, more especially on adding water and acids to it.

314. Pour three or four drops of aqueous sulphuric acid upon the fire, or upon a red-hot iron, where the fumes can be carried away; dense white vapours immediately appear.

315. Aqueous sulphuric acid should never be mixed with water in a glass measure, or any other thick glass vessel, as the sudden heat produced often causes them to be broken. Pour 3 ounces of water, by measure, into a thin flask, capable of holding 10 or 12, and mix with it in the flask 4½ ounces of the strongest acid. Great heat is immediately produced; if a tube with cold water be placed in the mixture, it soon begins to boil. If the flask be very thin, it may be dipped into cold water till it is nearly covered, when, if it be immediately removed, the small portion of water adhering to the glass outside evaporates quickly, and much vapour is observed.

316. Put a few chips of wood into a wine-glass, and mix them with a little of the acid; the wood is decomposed, and becomes black from the separation of part of the carbon.

317. Take two beer-glasses with water, and put into each a drachm of the aqueous acid. Into one pour a few

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228. What tests detect its presence?
229. Name the experiments, and explain them.

drops of any solution of baryta; sulphate of baryta falls, in the form of a white powder. To the other add a few drops of acetate of lead in solution, sulphate of lead immediately appears as a dense white precipitate insoluble in nitric acid.

318. *Hydrosulphuric acid*, or *sulphureted hydrogen*, is found in a number of springs, and in some cases, as on part of the coast of Africa, it is said to exist even in the waters of the ocean, producing the offensive odour observed in sulphureous mineral waters. It is gaseous when uncombined, and extremely noxious to animal life.

319. Air containing a proportion so minute as a millionth part of this gas is offensive to many constitutions, and must prove prejudicial to all. Air containing one part in fifteen thousand has been known to produce deleterious effects. A case is recorded where three stout men were obliged to give up work in an atmosphere containing only one part in five thousand. Air containing one part in fifteen hundred kills small birds. A horse dies in an atmosphere in which one part is mixed with two hundred and fifty of air. In a pure form, it produces instant death; in a more diluted state, the most violent convulsions are induced, which occasionally terminate in death.

320. Mix, in a bottle with a bent tube (fig. 28), 440 grains of the sulphuret of iron in fragments, with 3 ounces of water and 490 grains (5 drachms by measure may be taken) of aqueous sulphuric acid. Hydrosulphuric acid gas escapes with effervescence, and may be collected in jars or flasks at the pneumatic trough (fig. 24). The sulphur of the sulphuret takes hydrogen from part of the water producing the gas; the iron takes the oxygen with which the acid produces sulphate of iron; it remains with the undecomposed water.

321. Heat a bar of iron to whiteness, at a smith's forge, and press upon the extremity a roll of sulphur, inclining

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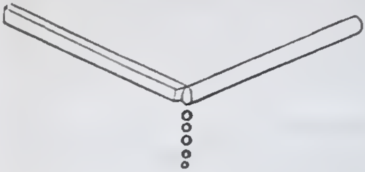
230. What of sulphureted hydrogen? its effects.
231. Cite the experiments given.

Fig. 38.



them in the manner represented in fig. 38, and collecting under water, in any iron vessel, the red-hot fluid which is immediately formed. It is the sulphuret of iron, very brittle when solid, and composed of 28 of iron and 16 of sulphur.

322. Invert a jar of hydrosulphuric acid gas, and apply a lighted match; the gas burns, and produces sulphurous acid and water as it acts upon the oxygen of the air; part of the sulphur is not consumed.

323. Fill a flask full of water, introduce a portion of the gas till it is half full, cork it under water, lift it out with the cork downwards, shake it well, and then loosen the cork, keeping the flask in the same position; the air rushes in to supply the place left vacant as the gas unites with the water. The solution is of the same nature with sulphureous mineral waters, but much stronger.

324. Moisten carbonate of lead with water, spread it upon a piece of paper, and introduce it into a jar or flask of the gas. The carbonate is immediately blackened, the dark coloured sulphuret of lead being formed, as the sulphur unites with metallic lead; at the same moment, the hydrogen of the gas combines with oxygen derived from the oxide in the preparation employed, and produces water.

325. Mix sulphate of lime (plaster of Paris) in fine powder with charcoal, and heat it to redness in a crucible after making the mixture into a ball with pitch or tallow, (see 312 and 313.) When cool, the mixture is found to have lost oxygen, the carbon having carried away, in the form of carbonic oxide, all the oxygen, both from the sulphuric acid and from the lime. It now smells strongly of hydrosulphuric acid, if water and an acid be added, for then the sulphur takes hydrogen from part of the water, while the oxygen of the decomposed water is attracted by

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232. Explain the experiments.

the calcium of the lime; the acid added combines with the lime and liberates the hydrosulphuric acid.

326. A similar action ensues in liquids containing sulphates in solution, as Professor Daniell has very recently proved; and to this he attributes the production of diseases in numerous marshes and other situations where sea water, which contains sulphates, is left in contact with animal and vegetable matter in a state of decomposition; the carbon it contains produces the same effect on the sulphates in solution as the dry carbon used in the preceding experiments.

327. *Symb.* $\vdots\mathrm{S}$. Sulphuric Acid. $\cdot\mathrm{H}\vdots\mathrm{S}$, Aqueous Sulphuric Acid. $\cdot\dot{\mathrm{H}}\vdots\mathrm{S}\&\mathrm{SFe} = \vdots\mathrm{S}\cdot\mathrm{Fe}$ and $\dot{\mathrm{H}}\mathrm{S}$. Water, sulphuric acid, and sulphuret of iron, produce sulphate of iron and hydrosulphuric acid.

328. *Phosphorus* is a very inflammable soft solid, having the appearance and consistence of wax. It melts at 100, and boils at 550 degrees. When pure it is colourless, but more commonly it has a slight yellow tint.

329. Heat bones in an open fire, a white matter remains, composed principally of phosphoric acid and lime; by sulphuric acid the greater portion of the lime may be removed, and if the acid be now heated with charcoal, it removes oxygen, and the phosphorus is converted into vapour. This process is too complicated for beginners to attempt it.

330. Phosphorus being inflamed with great facility, it ought always to be cut under water, and never touched directly by the fingers; it gives a very severe burn when it touches any part of the body after it has been inflamed. When used in any experiment where no water is required, it ought always to be dried previously, by placing it between folds of bibulous paper.

331. Put 5 grains of dry phosphorus upon a tin cup, supported as in fig. 35, and placed upon a plate; inflame it, and cover it with a dry jar. The phosphorus unites

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233. What is phosphorus? its properties.
234. How is it prepared?
235. What precautions in using it?

with the oxygen of the air, and produces a solid acid, which falls down in the included air like flakes of snow.

332. Put 5 grains of dry and newly kindled phosphorus into a jar or flask full of oxygen, and capable of containing about 30 ounces of water; the phosphorus may be supported in a cup, and should be placed as low as possible in the vessel containing the oxygen. A very vivid light appears during the combustion of phosphorus in oxygen; an acid compound is formed, as above.

333. Place a thin slice of dried phosphorus (about 1¼ of a grain) between folds of writing-paper, and rub it briskly with a glass stopple. The heat produced by the friction soon inflames the phosphorus.

334. Cut under water ten slices of phosphorus, as thin, and not larger than the smallest wafers. Dry them cautiously on blotting-paper, taking care never to touch them with the hand, and then transfer them from the paper to a portion of tow or cotton, so that they may rest near each other. The tow or cotton being then placed on an iron cup, and covered with a jar to prevent external currents, the slow combustion which the phosphorus undergoes produces a white smoke which gradually increases, unless the temperature be very low, and ultimately the oxygen of the air is entirely consumed. Occasionally the phosphorus takes fire, illustrating what often takes place with other matters, as when oil, charcoal, and other substances, gradually absorb oxygen from the air, and produce a slow combustion, which terminates after a considerable lapse of time in an active and violent conflagration.

335. Melt 3 or 4 grains of phosphorus in a test tube, give heat till it boils for five or ten minutes, and allow it to cool. If a sulphur match be now introduced, it may be made to rub off a portion of the phosphorus, the heat produced enabling the phosphorus to take fire on coming in contact with the air.

336. Put 10 grains of phosphorus into an ale-glass with boiling water, and force oxygen gas upon it, pressing

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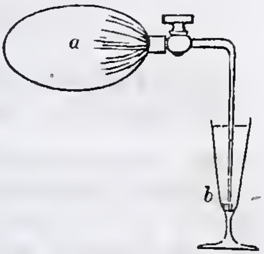
236. Repeat the experiments cited.

out the oxygen from a bag in the manner represented in the annexed figure. The phosphorus inflames under the boiling water.

Fig. 39.



337. Heat 30 grains of phosphorus with 30 drops of water and 30 grains of aqueous potassa, in a very small retort, till a gas is evolved which inflames as it comes in contact with the oxygen of the air. When the gas comes steadily away, the beak of the retort may be placed under water. Every portion of gas which rises through the water produces a beautiful wreath of smoke as it rises in the air. The gas is produced by one part of the phosphorus taking hydrogen from the water, while the rest takes oxygen and combines with the potassa. As it burns, the hydrogen forms water with the oxygen of the air, and the phosphorus also unites with oxygen.

338. Take a stick of phosphorus, holding it with pincers, and draw lines with it upon a wooden board in a dark room; whenever the phosphorus touches the wood, a portion is absorbed, which retains its luminousness for a long time. [Or dissolve a small bit of phosphorus in ether, and wet the hands and face with it in a dark room, and it will present the appearance of flame.]

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237. Describe the experiments.

CHAPTER XIV.

CARBON, CARBONIC ACID, CARBONIC OXIDE, COAL AND OIL GAS, COMBUSTION, PREVENTION OF SMOKE, VENTILATION.

339. *Carbon* is the term applied to an element very abundantly distributed throughout the globe, and familiarly known in an impure form in the condition of charcoal, coke, lamp-black, and soot. It is an infusible but combustible solid, burning freely when heated in contact with air, but remaining unchanged at all known temperatures when excluded from contact with the air and other substances. Carbon forms the principal part of coal, and also of all animal and vegetable substances. Its most important compounds are those which it forms with oxygen, hydrogen, and nitrogen, of which all animal and vegetable substances are principally composed, and in which they are associated in an endless variety of proportions. Carbon is found in many different conditions, of which the following ought to be more particularly noticed :—

I. The *diamond* is composed of pure carbon.

II. *Charcoal* consists almost entirely of carbon, and is prepared by heating wood so as to expel all the gaseous matter it contains. Heat a few chips of wood in a glass tube by the flame of a lamp, or in an iron pot placed upon a common fire, so long as gas and vapour are rapidly disengaged; charcoal is left, which must be excluded from the air as it is cooled, to prevent it from taking fire.

III. Heat common coal in the same manner; coal gas and other compounds are expelled. and the carbon is left as a cinder, forming what is commonly termed *coke.*

IV. *Lamp-black* is the carbon deposited from a smoky flame.

V. *Ivory-black*, or *animal charcoal*, are terms usually applied to carbon in the condition in which it is obtained

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238. Define carbon and its compounds.
239. Enumerate different conditions of carbon.

when bones are heated and the air excluded. A large portion of earthy matter is mixed with it in this condition, and in particular, a portion of lime uncombined with other matters, in addition to a large quantity of phosphate of lime. The uncombined lime is in many cases the cause of numerous peculiarities attributed in general to the carbon alone.

VI. *Plumbago*, commonly called *black lead*, is composed principally of carbon with a small quantity of iron.

VII. *Coal* consists in general of carbon, oxygen, hydrogen, and nitrogen, and is considered to have been formed from decayed vegetable matter. Few traces of animal matter have hitherto been observed. When heated, the gases are expelled, and carry along with them a quantity of carbon, producing common coal-gas, which burns upon the coal, if air be supplied to it, but may be conveyed, as in gas-pipes, to any distance if the air be excluded. Other gases are also formed.

VIII. *Splint coal* has a splintery fracture.

IX. *Caking coal* fuses, and forms a cake when heated.

X. *Cherry coal* has a slaty fracture, and is easily broken.

XI. *Cannel coal*, or *parrot coal*, gives much gas when heated, and was formerly used instead of candles.

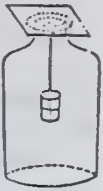
XII. *Glance coal*, or *anthracite*, consisting almost entirely of carbon, gives no gas when heated, but burns with a fixed light.

XIII. *Brown coal*, *bituminous wood*, or *surturbrand*, has a brown colour, and resembles peat.

XIV. *Jet* is another variety of coal; it is used in making black ornaments. *Naphtha*, *petroleum*, *mineral tar*, *mineral pitch*, *mineral caoutchouc*, and *fire damp*, are all composed principally or entirely of carbon and hydrogen, and considered as products of the decomposition of coal; substances similar to most of them being formed in preparing coal-gas.

340. Put some fragments of charcoal in a copper cup or cage; heat any of them to redness in a lamp, and introduce them into a jar, flask, or phial, containing oxygen (fig. 40). A brilliant combustion takes place, the charcoal burning with a fixed light. Carbonic acid gas is always formed when carbon is freely supplied with oxygen, whatever its source may be.

Fig. 40.



341. In the combustion of a common fire, where there is a thick bed of cinders, three circumstances require attention:—

I. Carbonic acid is formed below where the air first acts upon the carbon.

II. Part of the carbon of the superincumbent red-hot cinders takes away half of the oxygen from the carbonic acid as it rises through them, and 2 particles of carbonic oxide gas are formed by the decomposition of every particle of carbonic acid.

III. The 2 particles of carbonic oxide burn with a blue flame as they come in contact with fresh air, producing 2 of carbonic acid, as an additional supply of oxygen is communicated to them.

These changes may be thus expressed symbolically:—

I. $C\&O^2 = :C$. Carbon and 2 of oxygen produce carbonic acid.

II. $:C\&C = 2{\cdot}C$. Carbonic acid and 2 of carbon produce 2 of carbonic oxide.

III. $2{\cdot}C\&O^3 = 2:C$. 2 of carbonic oxide and 2 of oxygen produce 2 of carbonic acid.

342. In the preceding symbolic arrangements, the action that ensues between pure oxygen and carbon has alone been represented; but this illustration being one of great practical importance, the precise nature of the changes as they ensue between carbon and oxygen, as it is associated with nitrogen in air, should be carefully studied as they are represented in the following lines:—

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240. What of the combustion of charcoal?
241. Describe the combustion of a common fire.

I. $C\&2\cdot N^2 = :C\&N^2$. 1 particle of carbon and 2 of air produce carbonic acid and 2 of nitrogen.

II. $:C\&C\&N^2 = 2\cdot C\&N^2$. Carbonic acid and carbon, and 2 of nitrogen, produce 2 of carbonic oxide and 2 of nitrogen. In this and in the succeeding stage of the process, it will be observed that the nitrogen, liberated at first from the air, as represented in I., merely accompanies the other products without undergoing any change.

III. $2\cdot C\&N^2\&2\cdot N^2 = 2:C\&N^4$. 2 of carbonic oxide, and 2 of nitrogen, and 2 of air, produce 2 of carbonic acid and 4 of nitrogen.

343. In warm weather there is much moisture in the air, and the hydrogen of the watery vapour which passes through the fire produces with the carbon a gas, which, as it burns, changes a little the colour of the blue flame. The blue flame is usually seen most distinctly in very cold frosty weather, when the air contains little moisture, and when the fire presents a thick bed of cinders.

CARBONIC ACID AND CARBONIC OXIDE GASES.

344. *Carbonic acid* consists of 2 particles of oxygen and 1 of carbon. *Symb.* $:C$. Prepare carbonic acid gas at the pneumatic trough, using the bottle and bent tube represented in fig. 28, introducing into it an ounce of aqueous hydrochloric acid previously mixed with 2 of water, and about a table-spoonful of large fragments of chalk or marble, which are composed of carbonic acid and lime; the hydrochloric acid unites with the lime, and carbonic acid gas escapes with effervescence. *Symb.* $HCl\&:C\cdot Ca = HCl.Ca\&:C$. Two or three jars of gas may be collected, and a flask or bottle filled half full.

345. Introduce a lighted candle into one of the jars; it is immediately extinguished.

346. Invert another jar, and leave it without any cover

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242. Describe the effects of a moist air upon fire.
243. How is carbonic acid gas prepared?
244. What experiments are given?

for five or ten minutes; then try it with the candle as before: the carbonic acid gas being heavy, remains in the jar for a considerable time.

347. Shake the bottle with carbonic acid and water, the gas is absorbed. Add a little litmus in solution; the blue changes to a red. Boil a little of the red liquid in a flask or tube; the gas escapes. and the blue is restored.

348. Carbonic acid gas is fatal to animal life: animals introduced into it immediately die. Diluted with air to such an extent that respiration may be continued, it produces headache, oppression, dulness, and inactivity. It is evolved by the combustion of carbon, and by respiration; so that crowded or ill-ventilated apartments are extremely unwholesome, and sometimes dangerous, from the accumulation of carbonic acid. It is found during fermentation and putrefaction, and accumulates in old wells, pits, and caverns: before attempting to enter into any of them. a lighted oil-lamp should be introduced, and if extinguished, any one entering would probably be suffocated. [Brewers' vats are found to contain this gas, and the workmen by descending into them have often been the victims of their temerity or carelessness.] A candle is often extinguished in air vitiated with carbonic acid, though a lamp may burn in it, and gas burns for a short time in air so contaminated that neither a candle nor an oil-lamp can burn in it. [This gas is often generated to a fatal extent by burning charcoal in a close room, as in a portable furnace.]

349. *Carbonic oxide. Symb.* ·C. This is the gas that burns with a lambent blue flame on the top of a cinder fire. It may be procured most conveniently for experimental purposes in the following manner:

350. Heat 50 grains of crystallized oxalic acid in a retort with an ounce by measure of aqueous sulphuric acid. Collect the gases evolved at the pneumatic trough. The oxalic acid is decomposed and resolved into carbonic acid and carbonic oxide gases, as the hot sulphuric acid

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245. Name the effects of this gas, its sources, &c.
246. How is carbonic oxide prepared?

removes its water of crystallization. *Symb.* $:\mathrm{C}^2 = :\mathrm{C}\&\cdot\mathrm{C}$.

351. Invert a jar of the mixed gases, and pour into it as much lime-water as will fill it about one-third full. Shake the lime-water with the gases, keeping on the cover of the jar; carbonic acid gas is condensed, producing carbonate of lime, which renders the liquid milky. Inflame the remaining carbonic oxide; it burns with a blue flame.

COAL AND OIL GASES.

352. When coal, oil, tallow, wax, resin, and many other inflammable substances, are exposed to heat, gaseous compounds of hydrogen and carbon are produced in large quantity. In an open fire, the gas burns as it escapes from the coal, &c.; and an oil-lamp or tallow candle may be compared to a small gas manufactory, where the gas is consumed by the air as it is produced upon the wick.

353. Heat by a lamp some fragments of coal in a small test tube; gas is expelled, which may be inflamed. Water charged with ammonia and a tarry matter may also be seen as the heat is continued; coke is left in the tube.

354. When coal contains sulphuret of iron, hydrosulphuric acid gas is also formed, which is removed by lime. Ammonia is condensed by acids; and sometimes, instead of the more common acids, fatty matters are employed, many of which are regarded as peculiar acids.

355. The gaseous compounds of hydrogen and carbon are usually called *carburetted hydrogen gases.* The more they abound in carbon, the richer the flame they produce as they burn. *Hydruret of carbon* is more valuable than the *bihydruret*, and is found in larger quantity in oil than in coal gas. Their composition may be seen in the table, page 41.

356. The products of the combustion of carburetted hydrogen gases are carbonic acid and water, the nitrogen of the air being separated.

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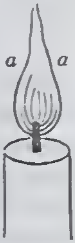
247. Name familiar examples of burning gases.

248. What is the name and chemical nature of these gases, and the products *of their combustion?*

357. Hydruret of carbon acts on 3 particles of air; carbonic acid and water are formed, and 6 of nitrogen separated. *Symb.* $HC\&3\cdot N^2 = :C\&\cdot H\&6N$.

358. Bihydruret of carbon consumes 4 particles of air, producing 1 of carbonic acid and two of water, 8 of nitrogen being detached. *Symb.* $H^2C\&4\cdot N^2 = :C\&2\cdot H$ and $8N$.

Fig. 41.



359. The flame of a common lamp or candle is produced by the hydrogen gas formed around the wick acting upon the oxygen of the air; it is confined solely to the exterior portion of the ascending gas. In fig. 41, *a a* denotes the part in a state of combustion. All without is merely heated air, or the products of combustion; and all within is unconsumed gas, rising in its turn to affect the oxygen of the air.

360. If a glass tube be introduced within the flame of a large lamp or candle, in the manner represented in fig 42, part of the unconsumed gas passes through it, and may be kindled as it escapes. With a tube $\frac{1}{4}$ of an inch in diameter, and a foot long, this is very easily shown; the wider the tube the better, if the flame be sufficiently large.

Fig. 42.

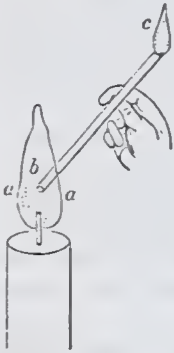


Fig. 43.

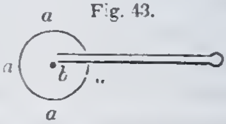
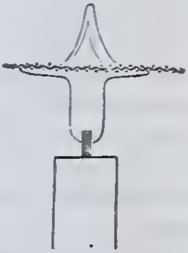


Fig. 44.



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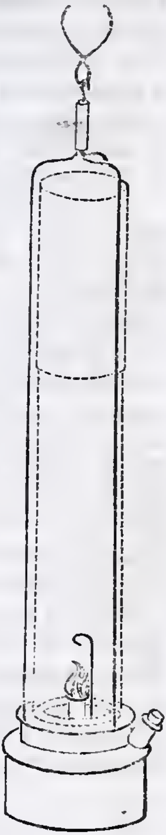
249. Define the flame of a lamp or candle, and the experiments cited.

361. Fig. 43 shows a section across the flame, with the position of the tube.

362. The nature of flame is beautifully illustrated by holding over the flame of a candle, or of a large stream of gas, a piece of wire gauze 6 or 8 inches square, with about 1000 meshes in the square inch. The flame is intercepted, and appears only below the gauze, a tube of flame appearing expanded as it reaches the gauze. The unconsumed gas rises through the gauze, and if a lighted match be applied, it burns on the upper side; the appearance is then presented, as seen in fig. 44.

363. A white heat is required to cause the combustion of common gaseous matter in most cases with flame, and an intense heat is equally produced by the combustion of gas with flame. If flame be produced on one side of wire gauze with small apertures, the metallic wires of the gauze being always kept cold by the surrounding air, any burning gaseous matter coming in contact with it is so much cooled, that it soon ceases to burn, and is incapable of inflaming unconsumed gas on the other side, after it shall have passed the gauze.

Fig. 45.



364. Fig. 45 represents the miner's safety-lamp, invented by Sir H. Davy, where a common lamp is surrounded with wire-gauze. In coal-mines, the atmosphere frequently becomes explosive, from the large quantity of bihydruret of carbon, the *fire-damp* of miners, which escapes from the coal as it is worked, and a lighted candle would instantly detonate the mixture. But with this lamp, though the explosive mixture may enter within the gauze and burn there, the flame with-

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250. How can the intense heat required for flame be prevented from communicating to surrounding gas?

in cannot set fire to the explosive mixture without, so that the miner has time to escape. If the current be strong, however, and the wire much heated at any one point by the flame being directed continually upon it, then it is apt to pass through the gauze, and set fire to the explosive mixture in the mines.

365. The intensity of light produced during the combustion of any gaseous matter, depends much upon the manner in which the gas is consumed. In producing a highly luminous flame, attention should be paid to the following circumstances:—

I. The combustion must be made to take place in such a manner that an intense heat is produced.

II. The gas, as yet unconsumed, is decomposed by the heat, and much solid charcoal is separated and suspended in the flame for an instant.

III. This charcoal must be intensely heated, so as to be consumed. Any unconsumed charcoal gives a yellowish tinge to the flame, and, if in large quantity, is deposited ultimately in the form of soot.

366. In an argand burner, fig. 46, the intensity of the heat is augmented by causing air to enter in the middle of a circular wick or series of gas jets, so that more gas is consumed within a given space than in the ordinary manner. Thus, in fig. 47, a section of the argand burner fig. 46, it will be seen that the surfaces of the burning gas *aa*, *aa*, are very near, so that the interposed gas is heated much more than when these surfaces *aa* are distant, fig. 48. Much carbon, therefore, is precipitated, and becomes intensely luminous before it is consumed.

367. If the aperture by which air is admitted into the interior of the flame be closed by a piece of paper, the flame represented in fig. 46 immediately assumes the form shown in fig. 48; part of the supply of air being cut off, it extends farther into the air before it meets with the oxygen necessary for combustion. The heat is acordingly

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251. What useful discovery of Sir H. Davy was thus made?

252. What circumstances modify the light furnished by inflamed gases?

253. Explain the principle of the argand lamp.

diffused over a larger surface, and becomes less intense; *a* and *a* are more distant from each other; a smaller quantity of carbon is deposited, less gas being decomposed, and even that which is separated being less intensely heated, much of it is unconsumed, and produces a dingy and imperfect flame.

Fig. 46.

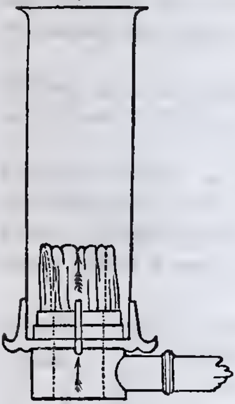


Fig. 47

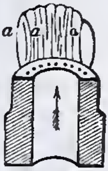


Fig. 48.

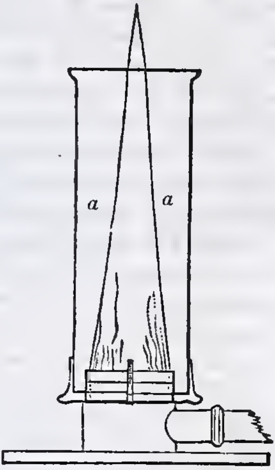


Fig. 49.

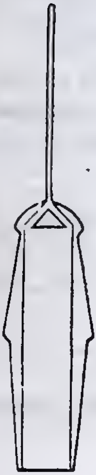
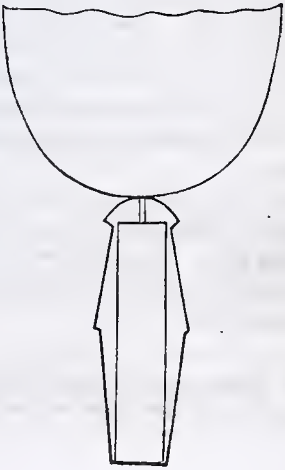


Fig. 50.



368. The most perfect form of burner is seen in the flat gas jet, fig. 49, where two opposing currents of gas meeting each other, flash into an extremely thin sheet of gas, which extends in an opposite direction to the currents which produce it. Fig. 50 is a section of the same jet, the side of the flame being turned towards the eye. Here, the gas on one side being so extremely near that on the other, all the conditions are fulfilled which are necessary for intense heat and light.

369. In the bat-wing burner, a similar but less perfect combustion is induced by causing the gas to issue from an open slit in the head of the burner.

370. For some purposes where gas is used, it escapes with too much force to be employed conveniently, as in experiments with the blowpipe. By placing over it a small brass tube, fig. 51, covered with wire gauze, a better flame for this purpose is procured.

Fig. 51.

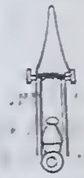
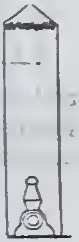


Fig. 52.



371. If air be mixed with gas before it is inflamed, as by allowing it to rise in a tin chimney, to which the air has free access on every side, wire gauze being placed over the top of the chimney, a flame is produced which is not more luminous than that of a spirit of wine lamp, and produces no smoke. Fig. 52 illustrates the arrangement adopted. It is easy in this way to procure a flame from an inch to a foot in diameter. Burners of this kind have been much used of late for the steady application of heat, both for domestic purposes and in the laboratory of the chemist.

372. Fig. 53 represents the roasting burner, in the manner it is manufactured by Mr. Milne of Edinburgh; it consists of a circular tube, from which numerous jets of gas escape, the meat being placed upon the upright spit in the centre.

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254. Describe gas burners of different kinds.
255. Can the heat of gas burners be rendered useful, and how?

FURNACES, FIRE-PLACES, VENTILATION.

373. If a fire be kindled in the middle of a room (fig. 54), the door, windows, and chimney, being completely closed, the air at the fire-place expands, and becomes lighter, bulk for bulk, than the rest, which descends and flows under it, pushing it upwards in the same manner as water poured into any vessel with a cork at the bottom, sinks under the cork, and floats it as it insinuates itself below it. A perpetual circulation thus goes on so long as the heat is continued, all the air being in time involved in this movement, cooling and sinking on the exterior, while fresh quantities are continually expanding as the heat affects them.

Fig. 53.

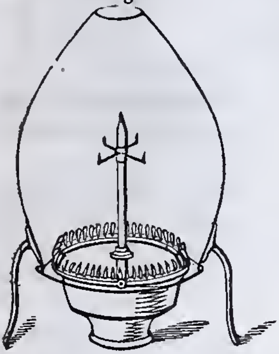


Fig. 54.

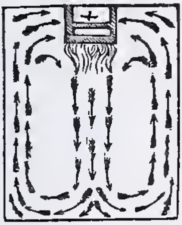
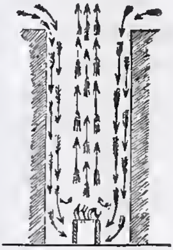
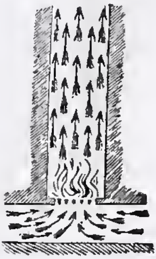


Fig. 55.



374. If a fire be kindled in an apartment or chimney, close below but open above, a current of warm air ascends, the cold air descending at the sides and forcing it up, so that the air is continually renewed; see fig. 55.

Fig. 56.



375. When a fire is heated in a chimney open below and above, the air moves quickly, the warm air in the chimney being pushed up rapidly by the external cold and heavier air, fig. 56.

376. When two chimneys are connected together by a flue (fig. 57), and a fire kindled in one of them, the air ascends in the one

with the fire, being pushed upwards by the cold air which descends through the other. A similar arrangement is adopted in ventilating numerous mines; the horizontal part of the figure may represent that part of the mine which is worked, and the perpendicular portions the two shafts which lead to the mine, the air descending in one and rising in the other.

Fig. 57.

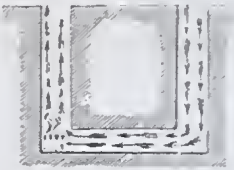


Fig. 58.

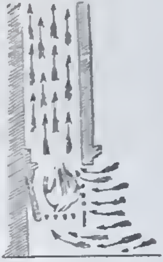
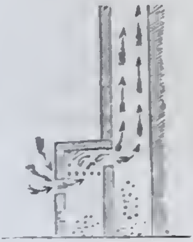


Fig. 59.



377. In fig. 58 the currents are represented as they occur in a common fire-place. Air enters by the doors or windows.

378. Fig. 59 illustrates the currents in a furnace. There, the space left open in a common fire-place being closed, a more intense heat is produced, as no air escapes into the chimney which does not pass through the fuel and contribute to the combustion.

Fig. 60.

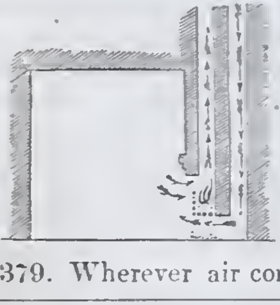
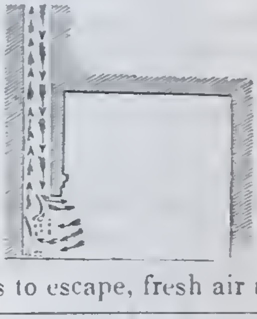


Fig. 61.



379. Wherever air continues to escape, fresh air must

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256. Describe the effect of a fire upon the air.
257. How has this been made useful in ventilating mines.
258. Explain the currents in a fire-place and furnace.

have free access to the apartment. When the doors and windows fit so tightly as not to admit of this, then some aperture must be made for this purpose alone. Fig. 60 represents a mode which has been occasionally adopted for this purpose, one chimney leading in a descending current of fresh air, while by the common chimney it is carried away.

380. When air is not admitted by this or some other arrangement, cold air descends in the chimney, entangling and carrying down some of the ascending warm and smoky air, and in such cases the room necessarily smokes; two currents, accordingly, an ascending and a descending current, perpetually affecting and interrupting each other, may be seen in all such vents. (See fig. 61.)

THE OPEN FIRE.

381. The general nature of the open fire-place will be sufficiently understood from the preceding illustrations. When properly supplied with air, there is no return of smoke, and the warmth it affords depends solely upon the heat which it radiates, unless it be conjoined with arrangements such as give it in some respects the character of a stove. This combination is not uncommon, the open fire being sustained in an iron frame, from which the consumed air is carried away by an iron pipe or tube traversing the apartment to be warmed, and communicating, accordingly, a considerable amount of heat, which, under other circumstances, would have passed away by the chimney.

382. Independently of the cheerful appearance presented by the open fire, it is distinguished by the purity of the heat it affords, and the constant circulation of air it maintains in the apartment in which it is placed. The less the quantity of metal, the greater the heat projected into the room. With large metallic bars and plates a great quantity of heat is continually withdrawn by conduction, as the air which passes by them ascends in the chimney. Sometimes polished brass plates are used with advantage

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259. Account for smoky chimneys.
260. What practical hints are given in relation to the open fire.

at the sides of particular fire-places, to reflect into the apartment any radiant heat which may fall upon them. Grates are almost invariably placed too high; branders supporting the fire should be on a level with the floor, and the ash-pit sunk below it.

383. The term draught is usually employed in reference to chimneys; and when air passes through them quickly, they are said to draw well. The movement begins with the expansion of the air in contact with the burning fuel, and the farther movement of the air depends upon the colder and heavier air meeting with less resistance than before from the expanded and lighter air in the chimney; and the greater the difference between the specific gravity of the external air and that in the chimney, the more rapidly does the movement go on, or, in common language, the better does the furnace draw.

384. If the smoke from a common fire be not carried up the chimney, and if there be sufficient air allowed to enter by the doors or windows, then, by closing the aperture between the top of the fire and the chimney, so that no air can have access to it except through the fuel, the smoke may in general be prevented from returning, for, by excluding the entrance of cold air above the fuel, the gaseous products in the vents are maintained at a higher temperature, and have consequently a greater ascending power.

385. The *smoking of a fire* may arise from a great variety of causes, among which may be more particularly enumerated :—

386. I. Interruption to the discharge, arising from too small a vent, or from the action of a current of air striking with force upon the chimney top. A movable cowl, which turns with the wind, often affords the best protection in such cases. Where the vent terminates below a high wall, from which the wind is reflected back upon it, producing a return of smoke, it is often necessary to carry the vent above the wall, that it may be beyond the influence of such currents.

387. II. The operation of currents in other apartments

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261. How may the smoking of a fire be remedied?

more or less distant. For example, if the external doors and windows of a house be so closely fitted that little or no air can enter by them, and if they should all be closed at the same time, while a large and powerful fire is maintained in any one apartment, as in the kitchen, it is obvious that air must descend through the smaller chimneys, even though fires be kindled in the fire-places connected with them, the great ascending power produced by the large fire in the kitchen overcoming all the minor draughts in the other apartments, and drawing air down through them, which, after producing an offensive smoke in them, and finding its way through the passages, arrives at the kitchen. The obvious remedy in this case is to admit air freely to the passages or to all the individual apartments.

388. It cannot be too particularly remembered, that air in contiguous apartments may be compared to materials poised with the most scrupulous care in the most delicate and sensible balance, and that air within any apartment stands in the same relation to the external air, other circumstances being the same. When from expansion induced by heat, or any mechanical impetus produced by the wind or any other cause, an increase of pressure is induced at one place, or a diminution at another, a movement in the air is the necessary consequence, and this ensues as certainly as a disturbance in the equilibrium of the pans of a nicely adjusted balance, when an increased weight is communicated to one, or a portion removed from the other.

389. Again, though smoke and heated air always tend to ascend, they may in numerous cases be very advantageously forced to take a descending movement in the first instance, where particular circumstances render it desirable that the surface of the fuel should be exposed, or when an ascending flue cannot be conveniently procured. In all arrangements of this kind a large flue or chimney is provided at first, in which all the smaller descending branches are made to terminate; and the air in it being

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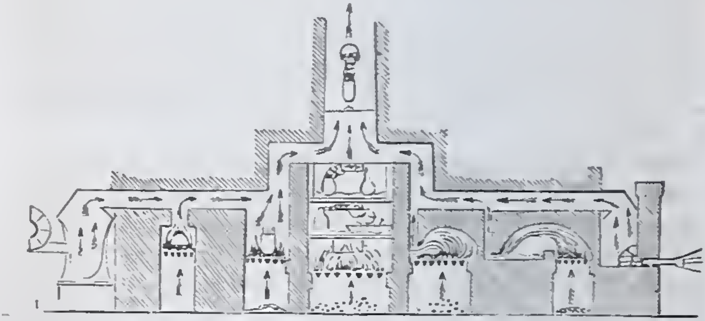
262. What varieties of ventilation are described?

heated, it draws downwards, horizontally, upwards or at any inclination, the air from all the apertures, and through all the branches that lead into it, provided it be sufficiently large.

390. It would be a great security against fire, and ensure a much more agreeable atmosphere, if all houses, whatever might be the number of apartments, were provided with one large chimney alone, all others leading into it. It would not then be difficult to prevent smoke in any ordinary atmosphere, the ascending movement from all the chimneys producing great strength in the current, so that it would resist any sudden gust of wind, such as would blow down any individual branch or small chimney, if left alone to contend against it. Some buildings are now in progress where numerous apartments are to be provided with flues according to this arrangement.

391. The two following figures illustrate the general arrangements adopted where many flues terminate in one large shaft or chimney, and should be studied carefully till the movement of the air in each individual compartment shall be distinctly understood; they represent some of the principal flues and furnaces attached to the large chimney in the centre of a chemical class-room, and the manner in which they enter in on every side, above and below ground; the arrows point out the course which the

Fig. 62.



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263. How might one chimney be made to serve all purposes?

different currents take till they reach the central chimney. In some extensive manufacturing establishments, from 100 to 200 furnaces often play into a single chimney, which may be seen occasionally at some distance, and rising alone in an adjoining field, underground flues conveying all the smoke to it. Such chimneys are often carried to a great altitude, in order to remove noxious fumes to a distance.

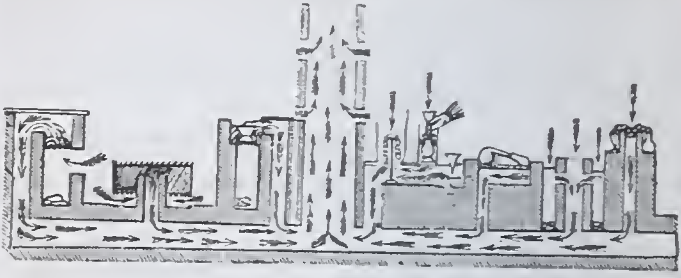
392. To the right, in fig. 62, a *smith's forge* is first observed; then a *reverberatory furnace*, where the flame dashes over the material to be heated; and then another furnace for miscellaneous operations. Below, and in the middle, a furnace is placed to heat the superincumbent iron sand-bath plate, evaporating basins being put there, while noxious fumes are carried away by the aperture represented. Above is another plate of a similar form, from which a more moderate heat is procured. A glass is also represented resting on a projection, and before an aperture in the chimney, so that offensive gases from it are rapidly withdrawn. To the left, the first furnace observed is used for operations where an intense heat is required; the large open space above the fuel allows all the consumed air to escape with rapidity, and fresh air to enter. A furnace, with an earthen vessel called a *muffle*, is next seen; it is used in refining gold and silver. A blast furnace for melting iron is observed at the extreme left; the air instead of entering through furnace bars, being propelled by a fanner turned two thousand times a minute by a steam engine.

393. In fig. 63 the other section of the same chimney is shown, illustrative of the arrangements adopted in several of the furnaces with descending flues, and of the manner in which fumes are carried off in numerous operations where the phenomena could not otherwise be so easily shown, without injury to the operator and those around him.

394. On the extreme right four apertures are seen for this purpose, which are used with different kinds of apparatus. The retort which follows rests upon a few cinders mixed with charcoal, the air descending as in the other flues, while the receiver is kept cold by the rapid current

of air descending on every side. In the next figure the experimenter is supposed to be introducing antimony or arsenic into a vase of chlorine surrounded by a glass chimney, and adjoining the chimney there is a large glass ventilator used for numerous experiments; naphtha is represented burning in a cup, the flame descending upwards of 12 or 18 inches. On the left hand, two furnaces are seen, well adapted for showing some crucible operations which require to be watched as they advance, and between them is observed a section of the circular fire by which the practical class-room is heated; it is about 3 feet in diameter, with a circular vent in the middle about 10 inches in diameter, which carries away the products of combustion: with a less powerful chimney than that into which it plays, the diameter of the vent would require to be 2 or 3 inches greater. Coke is usually employed in this fire-place, and the chimney is generally concealed from view by a wreath of blue flame, which descends within it, being produced by the combustion of carbonic oxide formed as described in page 112.

Fig. 63.



395. In the open fire, wood, charcoal, coal, or coke, may be used according to circumstances; some varieties of coke, however, and also the anthracite coal, do not burn unless the fuel be subjected to a powerful heat by constructing the fire-place so as to leave a very small portion of it exposed to the air.

396. In the arrangement adopted by Mr. Adams of

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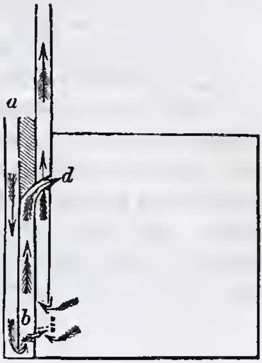
264. Explain the diagrams on this and page 124.

Falkirk for heating any apartment, the fuel is economized, and the air warmed as it is introduced. Cold air descends by *a* (fig. 64), and is heated by coming in contact with the back of the grate in the air chamber *b*; from it a small portion is allowed to enter near the fire by numerous openings, and the rest passes into the apartment along the floor; or, where this cannot so conveniently be done, it may be introduced above as at *d*, or at a little distance from the chimney. It is obvious, however, that it is not necessary that any of the air should pass directly from the air-chamber to the fire-place; if all of it be made to pass into the room, it must soon find its way into the fire-place, from the expansion produced there as the combustion proceeds.

Fig. 64.



STOVES.*

397. The stove is very different in many respects from the open fire, but more particularly from the circumstance that heat is communicated by it to the surrounding air largely by conduction, as the air comes in contact with it, independently of that portion which is radiated, whatever its temperature may be above that of the contiguous atmosphere.

398. Stoves are usually made of earthenware or of iron. The latter is generally preferred in this country, and iron stoves may be divided into different classes, according to the temperature to which the air in contact with them is exposed. The higher the temperature of the stove, the less pleasing is the quality of the air that comes in contact with it. Minute particles of dust or of any other sub-

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* For a description of hot-water apparatus, see "Communication of Heat."

265. Describe Mr. Adams's apparatus.

stances are often scorched and rendered offensive by it, while in extreme cases a portion of the oxygen of the air must be removed; the more intense the heat, the less is the amount of heating surface necessary, but when stoves are heated to redness, the air proceeding from them is apt to ascend at once to the ceiling of the apartment into which it is introduced, and to remain stationary there, while a comparatively cold atmosphere is observed below. The great object at all times should be to construct a stove with a very extensive heating surface, and to cause it to operate upon air before it enters the apartment to be heated, so that the great mass of heat it communicates may be delivered on the floor. If the lower stratum of

Fig. 65.

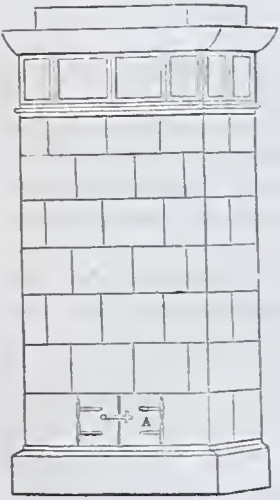
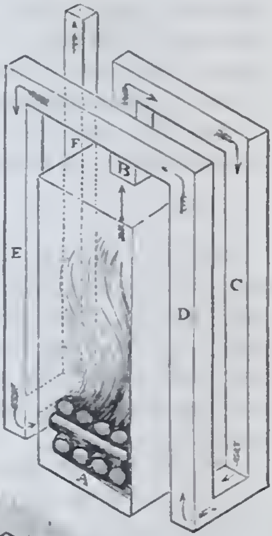


Fig. 66.



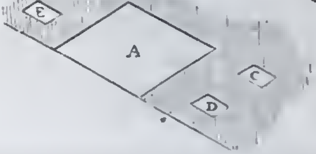


Fig. 67.

266. Describe the principle of stoves.

air be warmed, that above is certain to be warm also; but the air may be very warm above, without any sensible warmth being communicated to that portion which is below, and which comes in contact with the person.

399. Stoves are made of the form represented in fig. 65 in many parts of northern Europe, especially in Sweden, Russia, and Prussia. The fire rises to the top of a large apparatus employed, which is commonly made of earthenware: it then descends on one side, rises again on the same side, and passes to the other, where it descends and ascends as at first, after which it proceeds to the chimney. Fig. 66 indicates the various turns in the flues; and in fig. 67 a ground plan is given, the letters A B C D E F showing successively those communications through which the consumed air and smoke pass in the interior before the principal part of the heat is exhausted, after which they escape to the external air. A damper regulates the supply and escape of consumed air. A large surface is thus exposed to a very moderate degree of heat, and gives with great economy a mild and agreeable temperature.

400. In many stoves, and more particularly in those in which air is warmed at a distance from the apartment to which it is to be conveyed, the heated air is produced by allowing cold air to enter between the inner case containing the fuel and an outer case; the air is warmed as it passes, and may be conveyed by pipes to a distant apartment. The smoke is led into a chimney by a separate tube. (See fig. 68.)

401. Dr. Arnott estimates that three-fourths of the heat produced in a common fire-place is wasted or carried away by the chimney, and has proposed to employ an earthenware furnace enclosed in an iron box, so that a much larger portion of heat shall be obtained from the fuel, apertures being made in the iron chamber to regulate the currents of air. A great saving of fuel has been effected in this manner. Fig. 69 shows the general arrangement. Numerous stoves have been constructed in this manner; and

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267. What conditions are necessary in using stoves?
268. Describe the stove much used in Europe.

where the air is admitted with sufficient freedom at first, so as to produce carbonic acid, while the products of combustion are conveyed to a chimney where the draft is sure and certain, they are found to work well and prove very economical. If, however, the chamber for the fuel be overloaded, and the supply of air much too limited, carbonic oxide gas is apt to be generated, and in some cases even to explode, as it mingles with the air. Coke alone, or anthracite, can be used in these stoves.

Fig. 68.

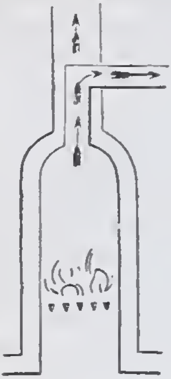
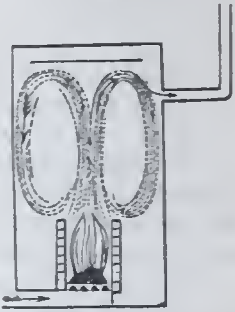


Fig. 69.



402. Again, in stoves where the heat is exhausted to so great an extent from the products of combustion, the ascending power in the chimney is small, and a returning draught is apt to take place, unless great attention be paid to the state of the currents.

403. It will also be observed that they do not ventilate or change a large amount of air, as in the common fire. Ventilation, accordingly, where they are used, must be provided by independent means.

404. The most certain method of providing securely against the evolution of noxious gases where such stoves are used, consists in arranging them so that they shall be absolutely air-tight within the apartment in which they are. the fresh air being introduced into the stove by an iron pipe from without, in the same manner as the chimney is attached for removing foul air.

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269 What precautions prevent the escape of noxious gases from stoves?

FURNACES.

405. In all cases where a strong heat is required, all apertures leading into the chimney above the place where the fuel rests, ought to be closed; and any of the apertures leading into the chimney from any furnace not in use, must also be shut, otherwise cold air rushing in by them reduces the temperature of the warm ascending current, and consequently reduces also the temperature in those furnaces in use, by preventing so rapid a consumption of the fuel. The general arrangements adopted in furnaces contrasted with those required in the open fire, are shown in figs. 58, 59, page 120.

406. If a single furnace be required, perhaps none will be found more generally useful than that represented in figs. 22 and 23. Another form is sometimes adopted (fig. 70), where it is not necessary to adapt it for iron bottles with attached tubes for the preparation of oxygen and other gases; if the flue be carried from 10 to 20 feet high,

Fig. 70.

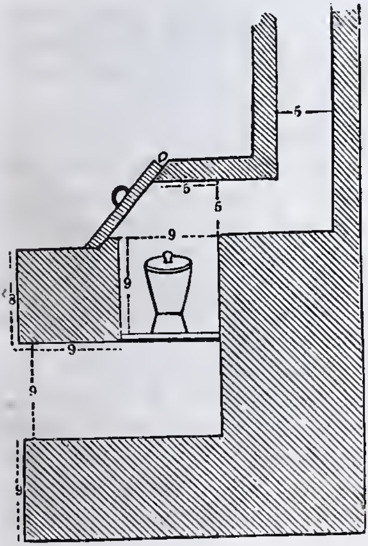
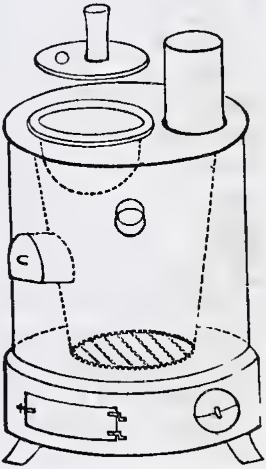


Fig. 71.



or be led into another chimney, it produces great heat. The numbers express the size in inches.

407. Dr. Black's portable furnace (fig. 71) is much used, and consists of a case of stout sheet-iron lined to the thickness of 2 or 3 inches with a very infusible clay or earthy composition. Above is an aperture for an iron pot to contain sand, and other openings may also be observed for introducing tubes and different kinds of apparatus. The pipe carrying away the smoke must be prolonged, or connected with a chimney.

408. All furnaces where a steady and regulated temperature is required, must be provided with ash-pit doors, by which a fixed and steady supply of air can be admitted, and regulated so as to produce a powerful or moderate heat. By cutting off altogether the supply of air, the combustion of the fuel may be entirely arrested.

409. Where many furnaces play into one chimney, if it be not sufficiently large, only part of them ought to be used at the same time.

410. Besides those furnaces in which the supply of air is maintained by a chimney, there are numerous varieties where the combustion is supported by the action of air propelled by a powerful bellows or some other mechanical power. The smith's forge affords the most familiar example of this kind of furnace. The cupola is another modification much used in melting iron. In the smelting furnace, which is used on the large scale in reducing iron and other metals from their ores, a powerful engine is employed to force in the large supply of air required, in cases where upwards of a hundred tons of materials may be often observed at a red heat at the same time.

411. Small portable furnaces, called *chauffers*, are found very convenient in numerous operations where heat is required; they may be made from 3 to 6 or 8 inches in diameter, and 6, 8, or 10 inches deep. A chimney put over them increases the heat (fig. 72). Tubes are often heated with them in the manner shown in figs. 73 and 74.

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270. Describe the furnaces named.
271 How many modes of ventilation?

Occasionally small crucibles are perforated and used as chauffers (fig. 75).

Fig. 74.

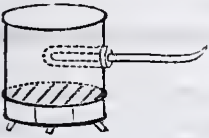


Fig. 75.

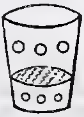


Fig. 72.

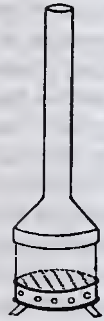
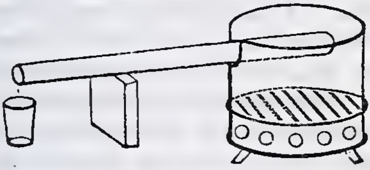


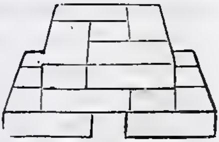
Fig. 73.



412. Chauffers are usually filled with red-hot cinders or charcoal. Wood heated in a common fire till all flame ceases, gives excellent charcoal for this purpose. When the chauffer is very small, charcoal alone is employed.

413. With 20 or 24 bricks, and a few small slips of narrow hoop iron, a chauffer or small furnace may be constructed in a few minutes, capable of giving a good red heat, where the usual facilities for operating are not to be obtained, and where a common fire is not accessible. Suppose the bricks to be 5 inches broad and 10 long, 3 are laid side by side as in fig. 76, and 3 more in the same way, and opposite to the first, at the distance of 4 inches. The slips of iron are placed in the middle to support the fuel, and one or two courses of bricks laid above them, so as to leave an aperture 5 inches square. If the bricks be laid with mortar or clay, the current of air will be still stronger, and the heat greater. By using

Fig. 76.



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272. Describe the apparatus named.
273. How may a temporary furnace be constructed?
274 What means may prevent smoke?

small pieces of charcoal, the heat may be moderated so as to be employed with flasks and retorts, as well as crucibles.

PREVENTION OF SMOKE.

414. In ordinary apartments, the prevention of smoke signifies rather the actual discharge of such smoke as may be produced in the fire-place by the chimney, than the regulation of the process of combustion in such a manner as to avoid in a great measure, if not altogether, its production. This discharge may be secured by attending to the illustrations given in the description of fire-places, stoves, &c., and in the succeeding paragraphs on ventilation. The remarks in the following paragraphs apply to different points not included in other chapters, but which require minute attention where it is a great object to prevent the production of smoke.

415. In the common fire-place, the amount of smoke produced may be diminished by regulating the amount of fuel with greater care than is generally taken, supplying it at more frequent intervals when particular kinds of coal are used which do not allow a large charge to be consumed slowly and equally, and by arranging it so that the air shall have free access to the smoke and gas as they are evolved; should they become cold before they mingle with the air, it is impossible to insure their combustion by any convenient process.

416. When fresh coal is placed on a very warm fire in full combustion, it removes much heat from it in the first instance, that heat being consumed in producing gas and expelling the various matters that are discharged either in this condition, or mechanically suspended in the gases. The word smoke, therefore, indicates an ever-varying mixture, in which the following substances more particularly may be traced:

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275. Define smoke, and its varied composition.
276. What causes unnecessary smoke?
277. Is perfect combustion of the fuel always desirable?

I. Bituminous matter mechanically suspended in the gaseous products, containing numerous oily and resinous compounds.

II. Carbon also mechanically suspended, and produced principally by deposition from part of the carbureted hydrogen gases decomposed by the heat to which they are subjected.

III. Unconsumed carbureted hydrogen gases. Those portions that are consumed produce flame.

IV. Carbonic acid gas, formed by the carbon and the oxygen of the air.

V. Carbonic oxide gas, formed by the imperfect combustion of part of the carbon.

VI. Nitrogen gas from the air.

VII. Unconsumed oxygen in variable proportion.

VIII. Watery vapour, produced by the hydrogen of the coal and oxygen of the air.

IX. Ammonia, a compound of nitrogen and hydrogen, formed as the coal is decomposed.

X. Sulphurous acid gas, formed by the combustion of sulphur in the coal with the oxygen of the air.

417. In large furnaces, where intense heat is required, or at all events a very great amount of heat, as in steam-boiler furnaces, much smoke is often produced, from the ineffectual manner in which the combustion is carried on. The gaseous products, in particular, are not consumed, being supplied in general, not with fresh air or oxygen, but rather with carbonic acid, carbonic oxide, and nitrogen gases, which result from the action of the air upon the cinders that constitute the lower stratum of inflammable matter, through which the air has to pass before it can gain access to the coal. The only effectual method of preventing smoke in these cases consists in admitting air in such a manner, and in such quantities, as to consume the whole of the inflammable gaseous products; many peculiar adjustments are required for this purpose in each individual furnace, according to the nature of the fuel

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278. What of imperfect combustion?
279. Define ventilation, and its need.

used, and the construction that may be necessary for the peculiar purposes to which it may be applied.*

418. In manufactories, the combustion of the carbonaceous and other inflammable matters in smoke is not always desirable, a deoxidating power being required, which is essential in some operations. In all other cases, the more perfect the combustion, the greater the amount of heat produced from the fuel used.

419. When the gaseous products discharged from any fire or furnace are invisible, the combustion may in general be presumed to be complete; this is not always a correct conclusion, however, as the invisible carbonic oxide is often evolved, indicating, where it can be detected, a deficiency in the supply of air.

420. Steam applied to carbon or smoke evolved by imperfect combustion, is decomposed when it approaches them at a sufficient temperature, forming with the carbon the invisible carbonic oxide and carbureted hydrogen gases; unless these meet with abundance of air, and be sufficiently heated, they are not consumed.

VENTILATION.

421. The process of ventilation consists in the renewal of air in any apartment, so as to insure the expulsion of all offensive products developed by respiration, combustion, or in any other way, and particularly carbonic acid, watery vapour, and effluviæ evolved either from animal or vegetable substances, or produced by chemical or other operations in buildings applied to manufacturing purposes, in mines, or any situation where the most free, direct, and open communication does not exist between it and the external air.

422. In the great theatre of the globe itself, natural ventilation is sustained by the varied currents induced in

* Those who are particularly interested in this subject may consult Mr. Williams's Treatise on the Combustion of Coal, and also a work on Ventilation, Respiration, Combustion, &c., by Dr. D. B. Reid.

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280. How is it provided for in nature?

the atmosphere, which not only tend to prevent stagnation in any individual place, but also to maintain a great movement continually in operation, by which the warmer air of the equatorial regions is conveyed to the temperate and polar regions, while they return a denser and colder atmosphere, which is again heated and circulated in the same manner as before. This vast movement in the atmospheric ocean is not supposed to be determined solely for the purpose of moderating the extremes of heat and cold, (see par. 181,) but it has also been considered that the luxuriant vegetation in the brilliant sunshine of warmer climes produces generally a purer air, and, in particular, absorbs much of the carbon of the carbonic acid which is found in minute quantity in the air in every part of the globe, and evolves oxygen in its place; thus giving to the temperate and polar regions a purer atmosphere than they would otherwise possess.

423. In the process of ventilation, the principal points that demand attention are the following:—The ingress and egress of air, and the nature of the moving power; the amount of supply required; the source from which the air ought to be taken; the filtration and purification of the air; the warming or cooling of the air; drying and moistening; the degree of diffusion that may be required; the discharge of the vitiated air; and the exclusion of all offensive products from drains or other sources which might be liable to injure the usual source of supply.

424. In all ordinary cases, the movement in the air required for ventilation may be sufficiently developed by natural causes, if one opening sufficiently ample be left for the ingress of air, and another of the same size be provided for its exit; a mechanical power may be used in particular situations, but the heat of the body, of lamps, candles, coal gas, fire-places, and furnaces, when in full operation, will be found sufficient, under all ordinary circumstances, to command the required movement. Mistakes productive of the most injurious consequences arise in general from the imperfect arrangements of the moving

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281. What circumstances are included in ventilation?

power, and from the supply of air being totally inadequate in numerous cases where many persons are crowded together in public assemblies. In extreme cases, where many people crowd closely upon each other, it has been found that there is in general one man upon each square foot, or two boys, the average age of the latter varying from seven to fourteen. It is rarely, however, that such dense crowds are observed, except upon a very limited area.

425. The air ought not to be taken from the surface of the ground, especially in damp situations or in cities, as the air there is often loaded with foul exhalations. Neither ought it to be taken in at the level of the chimney tops in streets, nor at any particular height where the opening by which it may have to enter is on a level with any other from which offensive fumes are evolved.

426. The amount of air required for each respiration may be estimated at twenty-two cubic inches for an adult; but as it is expired, it mixes with and contaminates so much of the contiguous air in confined apartments, that twenty cubic feet per minute are not considered too large a supply in warm weather. The higher the temperature, and the more largely the air is charged with moisture or any other extraneous matter, the more is required for respiration. Damp air arrests insensible perspiration; very dry air promotes it, and feels offensive from the rapidity with which it absorbs moisture. In winter, in situations where not more than one or two cubic feet per minute are given to each individual, ten, fifty, and one hundred, are frequently given with advantage in summer. Were the expense of warming, moistening, and drying the air not considerable, it would be proper to give a much larger supply in numerous cases than is generally allowed. In the same individual, also, great diversity is observed in the amount of the air that is most agreeable, not only from the state of the external atmosphere, but also according to the condition of the system, the nature of the temperament, the occupation that may principally engage atten-

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282. Whence should the air be taken for the purpose?
283. What proportion of air is requisite?

tion, and the period at which any refreshment may have been taken.

427. In numerous situations, more especially in populous cities, and in the vicinity of certain manufactories, or where particular natural impurities may be observed, much may be done, by filtration through cloths, to purify the air from impurities mechanically suspended in it, to condense sulphurous and other acids by lime-water, and to destroy peculiar contagious or other deleterious ingreents by the action of heat, acids, chlorine, and other chemical agents.

428. In warming air, the great object should be to heat the whole of the air in any apartment moderately, and to avoid local currents as much as possible. Air may be obtained comparatively cool by providing various apertures from which it may be taken, according to the circumstances of the moment; if these be placed so that air can always be taken from the shaded side of a house, and also cooled by the evaporation of water, spread out upon an extensive surface in vaults which the sun never penetrates, a very considerable reduction of temperature may be secured.

429. Moisture is communicated with facility to the air by the evaporation of water. It is required more particularly when cold air that has previously deposited its moisture is subjected to the action of heat. Lime is much employed in particular places for drying air; a few lime-shells placed in a damp apartment will in many cases remove moisture so freely, that it may be occupied without those injurious consequences which it is otherwise apt to induce.

430. Air cannot be admitted by too many apertures in crowded assemblies, or even in private dwelling-houses. When it is admitted by one or a few apertures only, it produces local currents such as have been so frequently referred to in the preceding chapters. In some apart-

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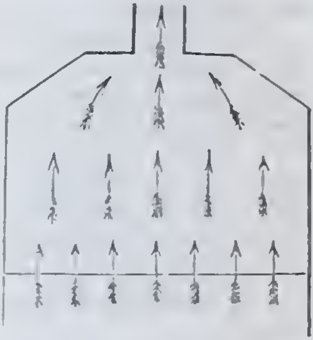
284. How is this proportion varied?
285. What chemical agencies purify air?
286. How are local currents to be avoided in ventilation?

ments lately built, the walls and floor have been constructed of porous materials, so as to give the greatest diffusion possible, and, consequently, the opportunity of introducing large supplies of air with the least possible impetus. In class-rooms, churches, and other places where fixed benches are constructed for each seat, each individual may be supplied with fresh air for his own consumption, instead of respiring that which in numerous cases has in part been respired previously by other persons. The diagram shows the general progress of the air in a public hall supplied from the floor alone, the air escaping throughout its whole extent from an air-chamber immediately below the floor, in which it can be heated to any temperature that may be required. The warmer the air, and the smaller the apertures by which it is admitted, the greater the amount that can be introduced in a given time without producing an offensive impetus on the person.

Fig. 77.



431. The diffusion of the air introduced forms one of the most important features of systematic ventilation, and becomes more and more imperative according to the crowded state of the apartments to be ventilated. Fig. 78 illustrates the general arrangements introduced for the ventilation of the present House of Commons, those that prevent the ingress of dust not being represented; 50,000 cubic feet per minute are frequently given in this house in very sultry and oppressive weather. The air in the chimney having been heated powerfully and expanded much by the furnace *k*, cannot oppose the colder air in the apartment, which accordingly presses it upwards, and is forced in the same course in its turn; fresh air accordingly

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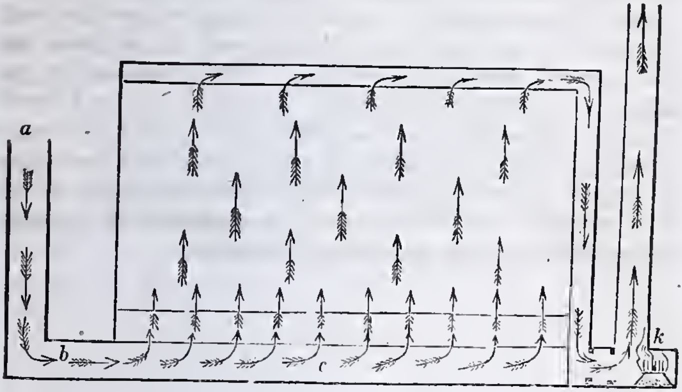
287. How is the diffusion of the air secured in the British House of Commons?

descends at *a*, and passes by *b*, *c*, through the apertures in the floor, rising in a slow but constant stream to the roof, whence it is conveyed to the chimney. Valves are placed so as to allow the rapidity of the current to be regulated according to the quantity of air required. A power is thus obtained capable of operating to any extent, and so completely under control that it can be adapted to the varying circumstances in which it may be applied, while it can also be easily regulated, and diminished or increased in an instant with the utmost precision. It acts upon air whether it may have previously been heated or cooled within the whole ranges of temperature observed at the surface of the earth, where no unusual circumstances present themselves.



432. Selenium and boron are similar in their general chemical relations to sulphur, phosphorus, and carbon, but are not so important, and require accordingly only a short notice in this place.

433. *Selenium* is a dark-brown solid, having a semi-

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288. Describe selenium and boron, and the compounds of the latter.

metallic lustre. It is insoluble in water, inodorous, and produces a strong smell of horse-radish when heated in contact with the air. *Symb.* Se—Equiv. 40.

434. *Boron* is an element which resembles carbon in appearance and properties. *Symb.* B—Equiv. 11? Its most important compound is *boracic acid*, which is a compound of boron and oxygen. *Symb.* ⁝B—Equiv. 35.

435. Boracic acid is a white solid, and is fused by heat. It is soluble in water and alcohol, and its alcoholic solution burns with a green flame. It is obtained by the action of sulphuric acid upon borax, which is a biborate of soda. The borax is dissolved in four times its weight of boiling water, and sulphuric acid diluted with four times its weight of water is added till the solution is acid, which is ascertained by litmus paper; it separates in crystals, the sulphate of soda remaining in solution.

CHAPTER XV.

CHLORINE, IODINE, BROMINE, AND FLUORINE.

436. *Chlorine* is a greenish yellow coloured gas, uninflammable, but supports the combustion of many substances. It was formerly called *oxymuriatic acid. Symb.* Cl—Equiv. 35·5. It has a pungent, suffocating odour, acts with great energy on metals, and numerous inflammable substances abounding in hydrogen. All vegetable and animal colouring matters, and offensive effluviæ from decomposed animal or vegetable matter, are quickly destroyed by it. Experiments with chlorine and its compounds should be performed, so that all the noxious fumes may be carried away, which are often very deleterious.

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289. What is chlorine?
290. What are the effects of chlorine?

437. Heat cautiously in a retort 1 ounce of binoxide of manganese in fine powder, with 3 ounces by measure of aqueous hydrochloric acid; put the acid first into the retort. Collect the chlorine gas at the pneumatic trough, having heated the water previously to 90 degrees; chlorine is condensed by cold water. Remove the retort when the gas comes slowly away, to prevent accident from the regurgitation of the water; this is apt to take place when the chlorine and the steam accompanying it are absorbed rapidly by the water.

438. Hydrochloric acid consists of hydrogen and chlorine, and two particles of it with one of binoxide of manganese produce chlorine gas, water, and hydrochlorate of manganese, which remains in the retort. *Symb.* 2HCl&:Mn=Cl&·H&HCl·Mn.

439. If a portion of chlorine gas be required quickly, put a table-spoonful of chloride of lime (common bleaching powder) into a jar, and pour upon it an equal bulk of aqueous hydrochloric acid, covering the jar lightly with a tray, that part of the air may escape. The hydrochloric acid unites with the lime, and displaces the chlorine; procured in this way, it is often used for some experiments, but must be considered very impure, and is mixed with air and carbonic acid gas.

440. Kindle a suspended candle, and introduce it into a jar of chlorine; it attracts hydrogen from the inflammable matter; carbon is separated, and the candle burns with a lurid flame.

441. Into a detonating jar, two-thirds full of chlorine gas, introduce coal-gas till it is filled, invert quickly and apply a light; an explosion ensues, the chlorine takes hydrogen from the gas, produces hydrochloric acid, and carbon is deposited.

442. Mix equal bulks of chlorine and hydrogen gases in a detonating jar, and apply a light; they combine with explosion, and produce hydrochloric acid gas.

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291. How is it prepared?
292. What of hydrochloric acid?
293. What experiments?

443. Pour antimony in powder through a funnel into chlorine gas; it takes fire as it combines with the chlorine.

444. Introduce copper leaf suspended in an iron cage into another jar; it also evolves heat and light as it combines with the chlorine.

445. Make a solution of chlorine in water, proceeding in the manner described in par. 314, page 111.

446. Add a portion of the solution to water tinged with vegetable blue; it is immediately bleached, the chlorine decomposing the colouring matter by taking hydrogen from it.

447. Chlorine is employed in numerous operations of art, from the many very valuable properties which it presents. It is used most extensively in combination with lime and water, forming then the compound termed *bleaching powder.* It is soluble in water, and acts most powerfully when an acid is added to detach the chlorine from the lime.

448. *Hypochlorous acid*, ·Cl, *chlorous acid*, ∴Cl, *chloric acid*, ⁙Cl, and *perchloric acid*, ⁙⁚Cl, are all compounds of chlorine and oxygen which are usually procured by indirect processes. They are not much employed in a pure form, but are produced in various operations when compounds containing chlorine are decomposed.

449. *Chlorous acid* is a transparent and very deep greenish yellow coloured gas. It is particularly distinguished by exploding with very great violence when subjected to a very moderate heat. Sometimes it explodes by the heat developed during its preparation, even when not more than three or four grains are used. It is usually prepared on a very small scale, by introducing four or five drops of aqueous sulphuric acid into a very stout glass, and allowing a grain or two grains of the chlorate of potassa to fall into it, the operator turning the mouth of the tube away from his face, as sometimes an explosion ensues when the materials come in contact. The gas is

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294. Uses of chlorine and its compounds.
295. What of chlorous acid?

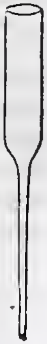
evolved as the aqueous sulphuric acid unites with the potassa. It is formed as part of the chloric acid which is then liberated loses one particle of oxygen, every two particles thus evolved combining with one of undecomposed chlorate of potassa, and forming perchlorate of potassa.

450. If hydrochloric acid be poured so as to cover a few grains of the same salt, chlorate of potassa, in a test tube, a very complicated reaction ensues, and chlorous acid is evolved; it is mingled, however, with a large quantity of chlorine. On introducing into the test tube a small wooden match, or a slip of paper, previously dipped in oil of turpentine, combustion immediately ensues. In this case, the reaction is not violent on the small scale, in consequence of the large amount of chlorine with which the chlorous acid is diluted. A larger portion of this gaseous mixture may be produced by mixing a teaspoonful of the salt with the aqueous hydrochloric acid in an ale-glass.

451. *Chloric acid* is the principal compound of chlorine and oxygen. It is usually employed, in combination with potassa in the form of chlorate of potassa. This salt is formed by the action of chlorine water and potassa.

452. Into an ale-glass put a teaspoonful of the crystals of chlorate of potassa, after filling it with cold water, and throw upon them five or six chips of phosphorus, each about the size of a pea. Fill a pipette (fig. 79) with aqueous sulphuric acid, allowing the acid at first to drop through it, that all air may be expelled, then leave it in the glass, the extremity resting upon the crystals of the chlorate. As the acid slowly descends, it takes potassa from the salt, and disengages a compound of chlorine and oxygen, which inflames the phosphorus under water.

Fig. 79.



453. Triturate briskly in a mortar half a grain of chlorate of potassa with as much sulphur; it quickly takes oxygen from the chlorate, producing an explosion.

454. Mix two grains of sulphuret of antimony, four of sugar, and twelve of the chlorate of potassa,

adding the latter cautiously on paper after mingling the two first, that there may be no explosion. If this mixture be heated, it takes fire at a very moderate elevation of temperature. If a portion be touched with a drop of strong aqueous sulphuric acid, lifted on the end of a slip of glass, chlorous acid is immediately evolved, which inflames the mixture.

455. Mix two grains of sugar with four of chlorate of potassa, a mixture is obtained which is affected much in the same manner as in the preceding case by heat and by aqueous sulphuric acid, though it is not quite so quick.

456. In both the preceding cases, when the mixture is inflamed as it is touched by the aqueous sulphuric acid, chlorous acid is liberated; and by its action with the inflammable matter of the sugar, the combustion is commenced, which is sustained actively by the large quantity of oxygen in the chlorate of potassa.

457. All these experiments must be cautiously performed; the gaseous compound of chlorine and oxygen explodes violently when gently heated. Many accidents have occurred from mixing chlorate of potassa and aqueous sulphuric acid in tubes and retorts.

458. *Hydrochloric* or *muriatic acid* is a gas (see page 95), which is condensed in large quantity by water, forming the common aqueous hydrochloric acid, and is often termed *spirit of salt*. *Symb.* HCl—Equiv. 36·5.

459. Heat strong aqueous hydrochloric acid as it is obtained from the manufactory; hydrochloric acid gas is expelled from it, and may be collected in a flask or bottle as shown in fig. 80. When full of gas remove the tube, close the mouth by the thumb, and place it, with the mouth downwards, under water coloured by vegetable blue; on removing the thumb, the water is forced with great rapidity into the bottle by the pressure of the air; the

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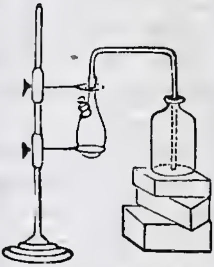
296. Name the experiment.
297. What of chloric acid and its compounds?
298. Why are precautions necessary in these experiments?
299. What is hydrochloric acid called? and its gas?

water combines with the gas, and the vegetable blue is reddened.

460. Mix two drachms by measure of aqueous sulphuric acid in a flask with an equal bulk of water; when cold, pour it upon 200 grains of common salt in a retort, and apply heat, introducing the beak of the retort into a receiver one-third full of water, which must be kept cold; the retort should be large enough to contain two or three times as much materials as are used, and the beak of the retort, though placed in the water, should not be put under it. The sulphuric acid causes a decomposition of the common salt, which is composed of chlorine and sodium, and of the water; chlorine from one and hydrogen from the other produce hydrochloric acid gas, which is condensed by the water in the receiver. Sulphuric acid and soda, composed of sodium and the oxygen of the water, remain in the retort, forming sulphate of soda. *Symb.* ⁝S&ClNa&·H=⁝S·Na&HCl.

Fig. 80.



461. Mix aqueous nitric and aqueous hydrochloric acids in a flask, and apply heat. Oxygen from the nitric and hydrogen from the hydrochloric acid combine and form water; nitrous acid and chlorine are then set at liberty. *Symb.* :⁝N&HCl=·⁝N&·H&Cl.

This mixture is termed *nitro-hydrochloric acid*, and also *aqua regia*, as it dissolves gold: it is much used in dissolving metals when chlorine is required.

462. Add a solution of nitrate of silver to a solution of chlorine or common salt in water, or to diluted hydrochloric or nitro-hydrochloric acid; a white curdy-looking compound immediately falls, composed of chlorine and silver; it assumes a dark tint when exposed to the light, and is termed *chloride of silver.*

463. *Iodine* is an opaque solid having a bluish black

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300. Explain the processes described here.
301. What is aqua regia, and why so called?
302. What compound of silver is named?

colour and semi-metallic lustre. *Symb.* I—Equiv. 126·5. It melts at 227 degrees, and boils at 350 degrees. Though very different in appearance from chlorine, it is similar to it in many of its properties; and has a pungent penetrating odour and an acrid taste. It is particularly distinguished by the deep violet-coloured vapour which it forms when exposed to heat. Iodine is dissolved sparingly by water, but in large quantity by alcohol.

464. Heat a few grains of iodine in a flask; a beautiful violet-coloured vapour is observed, which condenses slowly in crystals.

465. Mix a solution of starch with a solution of iodine in water; a blue compound appears—the iodide of starch. Put a little into a flask, and pour boiling water upon it till the colour disappears; immediately afterwards pour it into cold water, and the colour is restored.

466. Iodine is obtained from sea-weeds, after subjecting them to a number of complicated processes. A compound of iodine and potassium is much used for medicinal purposes, and in testing several metals.

467. Add a few drops of solution of the iodide of potassium to starch; no effect is produced. Add to the mixture a little chlorine water or aqueous sulphuric acid to unite with the potassium and detach the iodine; it immediately produces the blue iodide of starch.

468. When iodine occurs in combination with hydrogen, in the form of hydriodic acid, it has no action with starch; but if chlorine water or aqueous sulphuric acid be added, the iodine is liberated as in the preceding case, and immediately the starch is affected in the usual manner.

469. *Bromine* is similar in properties to chlorine and iodine. It is the only element that is liquid at natural temperatures, with the exception of mercury. It has a deep hyacinthine red colour, and produces a ruddy vapour, resembling in appearance nitrous acid vapour. Bromine is found in sea-water in combination with hydrogen. The

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303. Describe iodine, its physical and chemical properties.
304. Name the experiments.
305. How is it prepared? its compounds?
306. What is bromine, whence and how obtained?

saline matter being concentrated by the evaporation of the principal portion of the water, chlorine is added, which detaches the bromine.

470. *Fluorine* is an element which has not hitherto been obtained in a pure form. Its most important compound is hydrofluoric acid, which is a compound of fluorine and hydrogen. *Hydrofluoric acid*, also called fluoric acid, may be prepared by adding aqueous sulphuric acid to pulverized fluor spar, which consists of fluorine and calcium; the fluorine unites with the hydrogen of the water, and produces the hydrofluoric acid; the calcium and the oxygen of the water form lime, and this combines the sulphuric acid. It is transparent and colourless; it emits fumes on exposure to the air; it is particularly distinguished by forming a gaseous compound with silica, and cannot therefore be prepared in glass or other vessels in which this substance forms a part. It is used for etching on glass, but must be employed with extreme caution, as it is very corrosive.

CHAPTER XVI.

METALS.

471. Metals are said to be *native* when they occur uncombined with other substances; if in combination with other bodies, they are said to be *mineralized*. Metals are seldom obtained in a pure form in nature; they are generally combined with oxygen, sulphur, or chlorine, and often also with sulphuric, nitric, carbonic, and phosphoric acids. In preparing them from the minerals in which they occur, they are said to be *reduced* from their *ores*. Charcoal is employed to take away oxygen; and lime, carbonate of potassa; or soda, or iron, to remove sulphur and chlorine.

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307. Describe fluorine and its compounds and uses.
308. Describe native and mineralized metals.

Where there is much earthy matter mixed with the ore of a common metal, alkalies, glass, or other earths are added, so as to form a fusible compound with them, through which the metal may fall; the substance added is usually called a *flux*, as it promotes the flowing or melting of the different ingredients which might otherwise prevent the particles of the metal from running together.

472. Metals are distinguished by their peculiar lustre and opacity; many of them are very malleable and ductile, being easily extended into thin leaves or drawn into fine wire. They are good conductors of heat and electricity, unite with many non-metallic bodies, when they lose in general all their lustre, and assume an earthy appearance.

473. Compounds of metals with oxygen, chlorine, and iodine, are termed *oxides*, *chlorides*, and *iodides*. With sulphur, phosphorus, and carbon, the compounds are termed *sulphurets*, *phosphurets*, and *carburets*. When an acid, the name of which terminates in *ic*, unites with an oxide, the name of the acid in the compound is made to terminate in *ate*. Thus, nitric acid uniting with potassa produces nitrate of potassa.

474. The great mass of solid compounds observed at the surface of the earth may be considered as oxidated metals; and, accordingly, air being a binoxide of nitrogen, water an oxide of hydrogen, and the greater number of earthy compounds consisting of oxidated metals, it may be affirmed that the greater mass of the globe consists essentially of oxidated bodies. In the interior, unoxidated metals have been supposed to predominate, but on this speculative point different opinions are entertained.

475. The metals are divided into three great classes;—

I. *Kaligenous metals*, which produce alkalies when combined with oxygen.

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309. How generally found, and in what combinations?
310 What are properties of metals?
311. How are their peculiar compounds named?
312. Explain the terminating suffixes.
313. Where are oxidated metals abundant?

II. *Terrigenous metals*, which form earths of different kinds as they combine with oxygen.

III. *Calcigenous* or *common metals*, whose oxides have long been called *calces*.

476. The common metals are further subdivided according to the degree of force with which they attract oxygen, a point of very great importance in the history of metals. The following tables must accordingly be carefully studied:

I. Common metals whose oxides are not reduced by heat alone, namely—

Iron
Lead
Copper
Zinc
Antimony
Tin
Bismuth
Manganese
Chrome
Cobalt
Nickel
Arsenic
Vanadium
Cadmium
Tungsten
Molybdenum
Cerium
Columbium
Tellurium
Titanium
Uranium

II. Common metals whose oxides are reduced by heat alone, namely—

Mercury
Silver
Gold
Platinum
Palladium
Osmium
Rhodium
Iridium
Lantanium ?

477. *Malleable* metals can be altered in form, and be made to assume different shapes, without losing their continuity of form or texture. They are said to be *laminable* or malleable when they can be rolled into plates or beat into thin leaves, and *ductile* when they can be drawn into wires. Separate pieces of some metals can be united at a high temperature by mechanical means, and formed into any shape. In such cases they are said to be *welded*. Common gold leaf is about the 200,000th of an inch in thickness, but silver leaf is only 100,000th of an inch thick.

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314. How are the metals classified, and subdivided?
315. Explain *malleable, ductile, &c.. tenacity, fusibility, &c.*
316. How are metals rendered fusible?
317. What purposes do fluxes serve?
318. Other means of reducing metals.

478. Metals are exceedingly opaque, but would probably all transmit light, could they be rendered sufficiently thin. Gold leaf transmits a greenish light. The *tenacity* of some metals, but more particularly of iron, is exceedingly great. An iron wire little more than two-thirds of an inch in diameter supports a weight of 549¼ pounds. The extent to which it is now used in the form of anchors, cables, machinery, bridges, buildings, wire ropes, &c., sufficiently demonstrates its importance in these respects. Next to iron, the metals having the most tenacity are copper, platinum, silver, gold, and zinc.

479. The *fusibility* of metals is exceedingly various. Mercury is fluid till cooled 72 degrees below the freezing-point of water; platinum is melted only by the most intense heat which furnaces can command. Lime, common salt, borax, compounds of potassa, soda, and other substances, are constantly used as fluxes in melting metals. They melt on combining with different substances in the ore, if they are infusible alone, and are employed for different purposes.

I. To give fluidity to materials with which metals may be associated in extracting them from their ores.

II. To combine, at the same time that they melt, with various ingredients in combination with the metals.

III. To spread over the surface of metals, and exclude the action of the air.

480. In reducing metals from their ores, one metal is often mixed with metallic compounds, so as to take the place of others, and separate those that are most valuable. In other cases metals are extracted from various combinations by galvanic arrangements. (See page 76, par. 219.)

481. In the principal chemical changes into which they enter, metals are prone to combine with oxygen or other substances, before they combine with non-metallic compounds; acids, in particular, do not combine with metals when they are not previously united with other bodies. Metals lose their brilliant lustre, and generally present the

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319 Explain alloys and amalgams.
320. What are potassium and soda? lithium?

appearance of earthy substances, when they combine with non-metallic bodies. Metals uniting with each other form *alloys*, and retain their lustre. *Amalgams* are metallic compounds containing mercury.

CHAPTER XVII.

POTASSIUM, POTASSA, NITRATE OF POTASSA.

482. The most important kaligenous metals are *potassium* and *sodium*, which, with oxygen, form potassa and soda. These have been termed *fixed alkalies*, as they are not easily converted into vapour; but ammonia, the volatile alkali, is a gas at natural temperatures. The alkalies turn vegetable blue to green, yellow turmeric to a reddish-brown, corrode animal and vegetable substances, and form soaps with oily and fatty substances. *Lithium* is the name given to another alkaline metal which is comparatively rare, and has not as yet been applied to important purposes.

483. *Potassium* is procured from potassa, by heating it powerfully with charcoal or iron; the process requires much attention; none who are not well acquainted with chemical manipulation should attempt to prepare it.

484. Potassium is particularly distinguished by its extreme lightness, having a less specific gravity than water, so that it floats upon it when it is brought in contact with it. It is a very powerful chemical agent, having a great force of attraction, and entering into various combinations with the evolution of heat and light.

485. Throw a grain of potassium upon water: it takes fire and burns upon the surface of the water; potassa is formed, which is quickly dissolved.

486. Boil, in an iron goblet, 1 pound of newly-slaked

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321. Name the experiments.

lime, in fine powder, with an equal weight of carbonate of potassa and 10 pounds of water; the carbonic acid unites with the lime, the potassa is left in solution. Put the mixture into an earthen or glass funnel, obstructed by a few fragments of glass and a piece of linen cloth; collect the solution in bottles as it escapes, drop by drop. Exclude it, during its preparation and afterwards, carefully from the air, otherwise the potassa attracts carbonic acid.

487. Fused potassa (common caustic) is procured by evaporating the solution, and fusing by an increased heat the dry matter that remains.

488. Add a solution of potassa, of the carbonate of potassa, or of the bicarbonate, to water tinged with vegetable blue; a fine green is perceived. Add, drop by drop, aqueous sulphuric, nitric, or hydrochloric acid, to the green liquid; the acid combines with the alkali, and the blue colour is at last restored. Similar experiments may be performed with other acids.

489. The quantity of potassa in potashes or pearl-ashes is ascertained in the above manner, every 45 grains of aqueous sulphuric acid required to restore the blue colour in a solution of the alkali tinged by the colouring matter of the cabbage, indicating 45 of potassa = K+O. As acids and alkalies combine, they lose their causticity as well as their power of affecting vegetable colours, and are said to *neutralize* each other.

490. Burn a few small pieces of wood, collect the ash that remains, pour water upon it, and add vegetable blue. Potassa is found in solution, which turns the blue to a green. The potashes of commerce are prepared from the ashes of burned wood.

491. Expose pearl-ashes (impure carbonate of potassa) to the air in a cup or plate, it soon deliquesces. (See page 46, par. 114.)

492. Heat an ounce or two of nitre in a crucible; it soon melts, and if heated much, oxygen escapes, but no

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322. How may the strength of potashes or pearl-ashes be ascertained?

323. What salts of potash are named?

combustion is observed. While red-hot, pour upon it small successive quantities of sulphur and charcoal in fine powder, avoiding the fumes; the charcoal and sulphur burn quickly as they receive oxygen from the nitre.

493. Throw some nitre upon red-hot cinders; they burn with great rapidity.

494. Dissolve nitre in boiling water, so long as any is taken up; crystals of nitre in six-sided prisms appear as the solution cools.

495. Dip paper into the solution which remains above the crystals, dry it, and apply a light; it burns quickly, forming common match-paper.

496. Mix intimately 75 grains of nitre, 15 of sulphur, and 10 of charcoal. The mixture deflagrates like *gunpowder* when heated; machinery is required to give it the granular appearance of gunpowder.

497. Mix 600 grains of nitre, 200 of sulphur, and 100 of sulphuret of antimony. This mixture is termed the blue signal light, which is seen, when inflamed, at a great distance.

498. Nitre occurs in the soil in India, and is also formed artificially. In all deflagrating mixtures containing nitre, oxygen is rapidly transferred from the nitric acid to the inflammable matter.

499. Heat *bitartrate of potassa* (*cream of tartar*), consisting of tartaric acid and potassa, in a crucible; it is soon blackened, as the tartaric acid is decomposed. A small quantity held on a slip of glass presents the same appearance. Water poured upon the black matter dissolves the potassa; it may be tried by the vegetable blue, which becomes green as before.

500. Heat in the same manner equal weights of cream of tartar and nitre; the potassa of both remains united with carbonic acid, which is formed as the carbon of the tartaric acid unites with oxygen from the nitric acid in the nitre. In this manner very pure carbonate of potassa is formed.

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324. What ingredients compose gunpowder, the blue signal light, and other deflagrating compounds?

325. What is cream of tartar, and how prepared?

501. Add a solution of tartaric acid to a strong solution of any salt of potassa; crystals of cream of tartar soon appear. Cream of tartar is usually procured from the juice of the grape being deposited in crystals.*

CHAPTER XVIII.

SODA.

502. Soda = sodium 24 + oxygen 8. Sodium and soda are similar to potassium and potassa in all their leading properties. Soda is obtained principally from common salt and aqueous sulphuric acid, when the changes described in 640 take place. The sulphuric acid is withdrawn afterwards, and replaced by carbonic acid on heating the sulphate of soda with charcoal and chalk. Water dissolves the carbonate of soda, which is then crystallized, forming the compound usually termed soda.

503. *Kelp* and *barilla* are the ashes that remain after burning sea-weed. Soda has long been extracted from them by the action of water.

504. *Chloride of sodium* or *common salt* = 35·5 chlorine + 23·5 sodium = 59. When procured by evaporating sea-water slowly by the action of the sun in warm climates, after allowing it to overflow fields from which the sea is afterwards excluded, it is termed *bay salt*. *Pan salt* is obtained by boiling rapidly sea-water in an iron pan. *Rock salt* is the term applied when it is dug out of salt mines, many of which, of great extent, and containing often very pure salt, are found in different parts of the globe.

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* See experiments described under Chloric Acid, and Chlorate of Potassa, in page 145.

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326. Define sodium, and its source.
327. Kelp and barilla, how obtained ?

505. Common salt crystallizes in cubes, which are often associated so as to form hollow pyramids.

506. Throw some crystals of bay salt upon a red-hot plate of iron, they fall in pieces quickly with a loud decrepitating noise; the experimenter must avoid the fragments as the crystals break.

507. Dissolve common salt in boiling water, and add a solution of carbonate of soda; if common salt be pure, no effect appears, but if any magnesia be present, it soon appears as a white powder.

508. When magnesian salts are mixed with common salt, which is often the case, it is very apt to attract moisture, and acquires a bitter disagreeable taste; it is also much less fit for curing meat.

509. *Biborate of soda*, or *borax*, contains two particles of boracic acid and one of soda, with water of crystallization. Heat 200 grains in a crucible capable of holding 800; the water is expelled; the dry borax is fused into a transparent and colourless glass.

510. Mix a teaspoonful of powdered borax with an equal bulk of aqueous sulphuric acid in an evaporating basin; add half an ounce of alcohol. Heat the mixture and kindle the alcohol; the sulphuric acid unites with the soda, and the alcohol burns with a beautiful green flame, in consequence of the presence of the boracic acid.

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328. What is common salt chemically ?
329. Define bay, pan, and rock salt.
330. What of the presence of magnesia in salt ?
331. How does it crystallize ? experiments.
332. Experiments with borax, its properties.

CHAPTER XIX.

AMMONIA.*

511. Ammonia 17 = nitrogen 14 + hydrogen 3 = NH^3. A gaseous compound, alkaline like potassa, and often termed spirit of hartshorn, being formed when the horn of the deer and most animal substances are heated, the air being excluded; it is also formed in large quantity during the preparation of coal-gas. It is usually combined with hydrochloric acid, from which it is separated again by lime, to prepare it free from the offensive odour of animal matter, which at first it always presents. Being condensed in large quantity by water, it is usually employed in combination with this substance.

512. Heat half an ounce of strong aqueous ammonia in a small flask, receiving the gas, which is lighter than air, in another flask, as in fig. 81. The air is soon expelled, and then the flask must be removed, proceeding as described in 459. The coloured water is forced with great rapidity into the flask by the pressure of the air as the ammoniacal gas combines with it, and immediately becomes green.

Fig. 81.

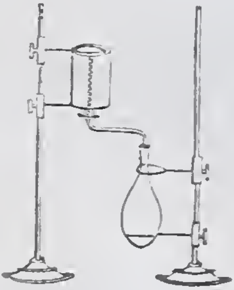

Fig. 82.

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* Ammonia is inserted here, though it contains no metallic matter, as it is very similar to the alkalies in most of its properties.

333. Define ammonia: how obtained?

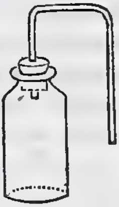
513. Put a drachm of strong aqueous hydrochloric acid into any flask, vase, or bottle, and a drachm of strong aqueous ammonia into another, then connect them by a tube passing through a cork which fits the bottle (fig. 82). White fumes of hydrochlorate of ammonia, or sal-ammoniac, immediately appear.

514. If no apparatus peculiarly adapted for the preparation of ammonia can be procured, mix 150 grains of hydrochlorate of ammonia with 100 of slaked lime in fine powder; heat the mixture in a glass retort by a lamp or chauffer, and condense the gas in a receiver half full of water. Shake the receiver frequently, but always keep the beak of the retort out of the water.

515. Hold test papers above aqueous ammonia; the ammoniacal gas escaping from the aqueous ammonia, affects them in the same manner as alkalies. Expose them to a very gentle heat, the ammonia is expelled, and the original colour is restored.

516. Prepare sulphureted hydrogen gas in a phial with a bent tube (fig. 83), passing the gas into an ounce of common aqueous ammonia contained in another phial; a large quantity combines with the ammonia; the solution is now termed *hydrosulphuret of ammonia*, and is often much used instead of sulphureted hydrogen gas in testing metals.

Fig. 83.



517. Dissolve oxalic acid in water, and add carbonate of ammonia till the solution no longer reddens the blue test-paper; the oxalic acid unites with the ammonia in the carbonate, expelling the carbonic acid with effervescence.

518. Heat a little of any salt suspected to contain ammonia with an equal bulk of slaked lime in a test-tube; ammoniacal gas is expelled if any be present, and may be recognised by its odour, or by the white fumes it produces when brought in contact with a rod dipped in hydrochloric acid. Soda or potassa may be used instead of lime.

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334. What experiments are cited?

CHAPTER XX.

LIME—PLASTER OF PARIS.

519. Earths are composed of metals and oxygen, in the same manner as the alkalies, potassa, and soda; four of them, lime, baryta, strontia, and magnesia, resemble alkalies; but they are not fused by heat, they are less soluble in water, less caustic, and form insoluble compounds with carbonic acid.

520. *Limestone, chalk, marble,* and *calcareous spar,* are composed principally of carbonic acid and lime, and are called *carbonates of lime.* Heat a few fragments of limestone or marble in an open fire; 50 parts of pure carbonate lose 22 of carbonic acid gas, and 28 of lime remain. In this condition it is termed *quick lime,* or *burned lime.*

521. Dip the quick lime into water, remove it immediately, and cover it. It soon swells, and falls to powder, combining with the water it had absorbed; the compound is termed *slaked lime,* or *hydrate of lime.*

522. Put a table-spoonful of slaked lime into a beer-bottle nearly full of water; shake the bottle, and allow the undissolved lime to subside; or filter, excluding the air, if a solution of lime be quickly required. It is termed *lime-water.* Try it with vegetable blue and turmeric in solution; it affects them in the same manner as alkalies.

523. Expose lime-water in any vessel to the air; it soon attracts carbonic acid, and a crust of carbonate of lime appears upon the surface. Mortar used in building is composed of sand and lime mixed with water, and hardens as the lime attracts carbonic acid.

524. Put 1 or 2 ounces of lime-water into a glass jar, and add carbonic acid water (347); carbonate of lime

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335. What are earths?
336. Which are called alkaline?
337. What are they composed of?
338. What is quick lime? and hydrate of lime? and lime-water?

falls; add more carbonic acid water, and the carbonate is dissolved. Many natural waters contain lime dissolved by excess of carbonic acid; exposed to the air, the excess escapes, and carbonate of lime is deposited, encrusting with a stony matter any substance upon which it may fall.

525. Pour aqueous hydrochloric acid diluted with twice its bulk of water upon fragments of carbonate of lime, so long as any effervescence appears. The changes described in 344 take place. Any mineral which dissolves with effervescence in diluted hydrochloric acid, and which gives a mass that slacks like lime, after heating to redness for some time, may be regarded as a limestone.

526. Take the solution of hydrochlorate of lime prepared as above (525); pour a portion into five or six wine-glasses; leave one as it is, and add different quantities of water to the rest. On mixing aqueous sulphuric acid with each, different phenomena are presented. Where no water is added the mixture becomes solid, sulphate of lime falls, composed of sulphuric acid and lime; hydrochloric acid gas escapes, which must be avoided. In the others, the hydrochloric acid is retained by the water, and the sulphate of lime is precipitated, unless a large quantity of water be present to dissolve it.

527. Mix with water powdered sulphate of lime (which has been heated previously to expel water) so as to form a thick fluid like cream. Put it in this condition into any mould, or upon any coin, so as to take an impression; it gradually combines with the water, and forms a solid compound. The powder is usually termed plaster of Paris, as the mineral from which it is made abounds at Paris.

528. Add a solution of carbonate of soda to a solution of hydrochlorate of lime; carbonate of lime falls, the other substances remain in solution.

529. Add oxalate of ammonia to any solution of lime, neutralizing it at first with ammonia if it be acid; oxalate of lime, which is very insoluble, immediately appears.

530. *Hydrochlorate of lime* in powder attracts mois-

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339. What experiments?

ture quickly from the air, and is much used in drying gases.

531. *Chloride of lime* is formed by exposing slaked lime in powder to chlorine gas. Water dissolves it abundantly, and the solution is much used as it abounds in chlorine. The chlorine acts most effectually when acids are added to detach the lime.

CHAPTER XXI.

BARYTA, STRONTIA, AND MAGNESIA.

532. *Baryta* is similar to lime, and is used principally as it detects sulphuric acid when added to any solution containing it.

533. *Strontia* also resembles lime. It is used in the preparation of deflagrating mixtures, where a bright crimson light is required. Mix hydrochlorate or nitrate of strontia with alcohol in an evaporating basin or metallic cup, inflaming it, and heating the mixture. The alcohol burns with a crimson tint. A large sheet of paper dipped in the mixture, and inflamed, shows the tint very distinctly.

534. *Magnesia* is found in bittern, the liquid that remains after boiling down sea-water for the preparation of common salt: it is there combined principally with sulphuric and hydrochloric acids. It is also found in some varieties of limestone, and in many natural waters. Magnesia is mild compared with the preceding earths, and does not corrode animal substances, so that it is often given medicinally to neutralize acids. It is very sparingly soluble in water.

535. *Sulphate of magnesia*, or *Epsom salts*, contain

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340. What compounds of lime are named?
341. Define baryta, strontia, and magnesia.

sulphuric acid and magnesia; they are prepared by crystallization from bittern, or from natural waters in which it abounds. Many fatal accidents occurring frequently in consequence of oxalic acid being mistaken for Epsom salts (sulphate of magnesia), the following characters ought to be studied experimentally; the last two may be seen by putting the materials in small quantity upon a slip of glass, adding the tests in solution.

Tests.	Oxalic Acid.	Sulphate of Magnesia.
Taste,	Acid,	Bitter.
On red-hot cinders,	Dissipated,	White mass left.
Vegetable blue,	Reddened,	No effect.
Alkaline carbonates,	Effervesces,	White precipitate.

Symb. of oxalic acid. $\vdots\mathrm{C}^2 = \mathrm{O}^3 + \mathrm{C}^2$, or $= \cdot\mathrm{C} + :\mathrm{C} = 36$.

CHAPTER XXII.

ALUMINA—SILICA.

536. *Alumina*, or oxide of aluminum, abounds in clay, and is distinguished from preceding earths by its insolubility in water, and by being soluble in a solution of potassa. When uncombined, it is insipid and inert.

537. *Alum* is one of its principal compounds, and contains alumina, potassa, sulphuric acid, and much water of crystallization. Its solution reddens litmus, but scarcely affects cabbage.

538. Add a little ammonia, potassa, or soda, to a solution of alum; it unites with part of the acid, and the alumina falls.

539. Heat alum in a red-hot iron cup; it soon melts, water of crystallization is expelled, and a spongy mass is obtained, termed *burned alum*.

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342. What is Epsom salts?
343. How distinguished from oxalic acid?
344. Define alumina and alum; uses.

540. *Common clay* may be fused by a sharp heat, and becomes red before it melts, the iron it contains attracting oxygen.

541. Fire-clay is less fusible, and is used in preparing bricks, which may be exposed in furnaces to a strong heat. Fine varieties of clay are used in the manufacture of *crucibles*, *pottery-ware*, and *porcelain*.

542. *Silica* consists of silicum 22 + oxygen 8; it is, like alumina, a very abundant earth, constituting the principal ingredient of flint, of the sand of the sea, and of the desert, and of many rocks and minerals. Quartz is composed of silica nearly pure. Silica, in its ordinary form, is insoluble in water.

544. If sand or any silicious compound, such as glass, be mingled with aqueous sulphuric acid and fluor spar (par. 470, page 149), the hydrofluoric acid that is disengaged on the application of heat combines with part of the silica, and forms a transparent colourless acid gas. It produces fumes when exposed to the air, but is particularly distinguished by the manner in which it is decomposed if introduced from the beak of a retort in water, the hydrofluoric acid combining with the water, while the silica is separated in the solid form. The experiment may be performed with a small glass retort containing 100 grains of each material. The retort is generally corroded in one or two operations.

544. Mix intimately 200 grains of fine sand, and 600 of pure carbonate of potassa; fuse the mixture in a crucible capable of containing four times as much. Carbonic acid escapes, the silica and potassa combine and produce glass. Pour out the glass, which is commonly termed *silicated potassa*, on an iron-plate, and dissolve it in water, the large quantity of alkali rendering it soluble in this fluid. The compound formed in this manner constitutes pure *silica soap*, having all the detergent properties of common soap; it is more active than ordinary soap, and leaves a harsh feeling upon the hand. Common silica

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345. What is silica, and where found?
346. What of its compounds?

soap is mixed with a considerable portion of common soap, and occasionally with sand.

545. Add to the solution hydrochlorate of ammonia, also in solution. The hydrochloric acid of the hydrochlorate unites with the potassa of the glass, and the silica falls.

546. With less alkali, glass is formed insoluble in water. *Common bottle glass* is made of coarse sand, and any alkaline salt or earthy matter which can render it fluid when heated. *Plate* and *window glass* are made with purer sand and alkali. *Flint glass* is composed of similar materials, with the addition of oxide of lead, which gives more weight and lustre to the glass, and also allows it to be worked at a reduced temperature.

547. *Coloured glasses* are formed by heating glass with various metallic oxides. Cobalt gives a fine blue; with manganese an amethystine tint is seen. Gold produces a ruby colour; copper and chrome give green, and arsenic makes it of a milky whiteness.

548. All vessels made of glass must be cooled slowly after they are made, or annealed, as this is termed, otherwise they are very easily broken. When a piece of any fused rock or glass is cooled with extreme slowness from a high temperature till it becomes solid, it crystallizes, and presents the appearance of a stone. But if cooled quickly, a glassy substance is observed.

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347. What is said of the manufacture of glass?
348. How is glass coloured?

CHAPTER XXIII.

COMMON METALS.—IRON.

549. This, the most important of the metals (see par. 21, page 23), is found in a great variety of forms at the surface of the globe, and is obtained principally from various ores in which it is combined with oxygen. These are sometimes nearly pure, and then, by the action of carbon alone, the metallic iron is procured, as the carbon removes oxygen on the application of heat. In this country the ores more commonly employed, which are termed clay-iron ores, require the addition of lime, which forms a fusible compound with the other earthy matter in the ore, through which the iron falls with facility when the carbon has removed the oxygen.

550. In many places the air propelled into the furnace for preparing the iron is heated previously by passing it through red-hot iron pipes. If cold air be blown into a furnace, its first effect is to cool the fuel and other matters with which it comes in contact, at the very point where the greatest intensity of heat is required, however great the heat may be that is afterwards developed. When the air is heated previously, the greatest intensity of heat is produced at the point where it is most important that the temperature should be as high as possible. When air at ordinary temperatures is used, the furnace is said to be a *cold blast furnace*, but when warm air is employed, it is called a *hot blast furnace*. In all blast furnaces the great intensity of the heat fuses all the earthy substances, which are run off from time to time in a liquid form, these consolidating as they cool into a glassy or stony-looking mass usually termed *slag*. The melted iron which accumulates at the bottom of the furnace is

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349. Where is iron found, and in what state?
350. Describe the processes of reduction?
351. What varieties of iron are named?

also allowed to run out from time to time by tapping the furnace, being received into numerous furrows made in sand; from these it acquires the form in which it is usually observed.

551. *Pig*, or *cast iron*, is the term commonly given to iron as it is prepared from the clay-iron ore. It is more brittle and fusible than pure iron, in consequence of the presence of aluminum, silicum, and carbon in small proportion. It varies much in strength and fusibility, according to the source from which the ore is obtained, and the manner in which it is treated at different iron-works. *White cast-iron* is much harder and more brittle than *gray cast-iron.*

552. *Malleable iron*, termed also *soft*, *wrought*, *or forged iron*, is prepared from common cast-iron by different operations. It is melted in the *refining* furnace, where a considerable quantity of impurities is separated. It is then transferred to the *puddling* furnace, a particular kind of reverberatory furnace (par. 392, page 125), where, after being melted, it is stirred assiduously till it becomes reduced to a solid form, presenting the appearance of a very coarse-looking granulated mass. By increasing the heat, it is then formed into balls, diminishing in fusibility as it increases in tenacity and purity. Lastly, by hammering it, and pressing it between rollers, the more fluid impurities still adhering to it are squeezed out, and it then forms the malleable iron of commerce.

553. Where a very pure oxide of iron is obtained at first, malleable iron is at once procured when the oxygen is removed.

554. Steel consists of iron and a small portion of carbon, varying from 100th to 150th part of its weight. It is usually formed by the process of *cementation*, an operation in which malleable iron, embedded in charcoal, is exposed for several days to a steady heat in a furnace. Steel is particularly distinguished by the extreme hardness which it acquires, if it be cooled suddenly after exposing it to heat. The *tempering* of steel consists in

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352. How is malleable iron made?
353. By what process is steel made?

cooling it after exposing it to a particular temperature, so that it may acquire as it cools that particular quality or texture which may adapt it more especially for the purpose to which it is to be applied.

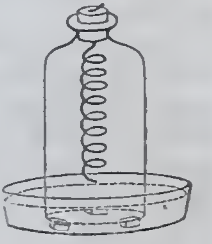
555. Iron is a metal which is extremely prone to rust when it comes in contact with air and moisture. In air absolutely dry, and in water absolutely free from air, it undergoes no change; but when both act upon it at the same time, the absorption of oxygen is rapid, particularly if any acid be brought in contact with the mixture. Even carbonic acid is powerful in promoting the oxidation of iron, if mingled with the water brought in contact with the iron. Iron becomes still more liable to rust and decay, if it be at the same time made to touch another metal, such as lead, which induces a galvanic action that facilitates the absorption of oxygen. But iron brought in contact with zinc, and even a solution of the hydrochlorate of zinc, resists the oxidating influence of the air.

556. Put a teaspoonful of iron-filings on a plate, moistening them from day to day till they become *rust*, by attracting oxygen from the air, and a little carbonic acid and nitrogen.

557. Moisten a similar quantity in any flask or jar, and pour cautiously an equal bulk of aqueous nitric acid upon them. It is rapidly decomposed; nitrous acid escapes, and the iron is oxidated.

558. Prepare a coil of thin iron-wire, tie a thread at the extremity, dip it in melted sulphur, inflame it, and introduce it into a bottomless bottle of oxygen, after placing it in a basin with water, as in fig. 84, with a plate of iron, or some sand, below. The iron oxidates, the oxide melting and falling through the water.

Fig. 84.



559. Mix, in a flask or jar, the materials employed in preparing hydrogen, using iron instead of zinc. (See

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354. What agents rust iron, and how?
355. What experiments?

248, 249, and 259.) Filter the liquid procured, and, if no crystals appear, evaporate the solution, and set it aside, that green crystals of *sulphate of iron* may be formed.

560. The *black oxide* of iron, called by many the oxide, is a combination of the oxide with the peroxide; the oxide is obtained with difficulty in a pure form, on account of its tendency to absorb oxygen from the air. Fill a crucible half full of crystals of sulphate of iron, and expose it to a dull red heat, *red oxide* of iron, called also *peroxide*, remains; the oxide in the sulphate attracting oxygen from part of the acid as it is expelled by the heat.

561. Compounds of the oxide with acids are usually green, but the red oxide, which is nearly the same as rust, produces reddish compounds. Mix an ounce, by measure, of aqueous hydrochloric acid with six ounces of water and a small tablespoonful of the red oxide in a flask; keep the mixture in a warm place for some hours, shaking it occasionally, and filter it afterwards, to separate the solution from any excess of iron. The compound is termed *perhydrochlorate of iron.*

562. Mix 500 grains of flour of sulphur with 1000 of bright iron-filings in a Florence flask, and heat it on a chauffer of red-hot cinders. Heat and light are evolved as they combine, and sulphuret of iron is formed.

563. Dissolve 50 grains of sulphate of iron (*green vitriol*) in 2 ounces of water, and pour a few drops into 6 glasses, jars, or flasks, previously filled nearly full of water.

I. Into one pour potassa in solution; oxide of iron falls, combined with water. Expose it to the air; it slowly attracts oxygen, and becomes rust.

II. To another, add carbonate of potassa; carbonate of iron falls.

III. Add a little of the third to a large quantity of lime-water; oxide of iron is again precipitated.

IV. Add ferroprussiate of potassa in solution to the fourth. (See 4.)

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356. Name the compounds of iron cited.

V. Add to the fifth a drop of hydrosulphuret of ammonia; sulphuret of iron is precipitated. $HS + NH^{3} \& \vdots S \cdot Fe = SFe \& \cdot H \vdots S + NH^{3}$.

564. In all these experiments, the sulphuric acid remains in solution with the alkali or earth in the precipitating solution employed.

VI. Add an infusion of galls to the sixth; gallate of iron, the colouring matter of ink, slowly appears.

565. Dilute a little ink with water, and add chlorine water or oxalic acid; the colour disappears.

566. Repeat all these experiments, using a solution of the perhydrochlorate of iron diluted in the same manner as the sulphate. Observe the difference of tint in most of the precipitates formed from this solution.

LEAD.

567. *Lead* is a malleable and sectile metal, of a bluish-gray colour. It is employed in numerous processes of art, and is very generally used for protecting roofs, conveying water, and lining cisterns containing it. It is speedily oxidated by exposure to air and heat, and some waters corrode it rapidly, while others exert little or no action upon it. (See par. 228, page 79.) Minute quantities of different salts protect the lead from corrosion, 1 part of sulphate of soda in 4000 of water, or 1 part of phosphate of soda in 27,000, being sufficient for this purpose; in these cases, the phosphoric and sulphuric acids form compounds with a minute quantity of the lead, which adhere so tenaciously to it that they prevent further corrosion.

568. Lead also is particularly distinguished by the poisonous properties observed in many of its compounds. Few substances have proved more noxious in this respect than sugar of lead; in many cases death might have been prevented had the properties of this substance been known. It may be recognised with facility by merely heating a small portion about the size of a pea over the

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357 Cite and explain the experiments.
358. Define lead and its uses.

flame of a lamp or candle, when the following appearances are successively observed:—Fusion, boiling (from the water of crystallization escaping), after which a dry white mass is left, dry fusion, escape of acetic acid, producing a smell of vinegar, the fused material becoming successively black and brown, and ultimately taking fire; after which red and yellow oxides of lead, and metallic lead, may then be observed.

569. Heat lead to redness in a crucible or iron ladle; it soon oxidates if exposed to the air, and the oxide melts. *Red oxide*, or *yellow oxide* of lead, in powder, is obtained if it be cautiously heated without being fused. Observe the beautiful iridescence as, on removing the oxide from the surface, a fresh portion of metal is exposed to the air.

570. Dissolve 220 grains of acetate of lead (sugar of lead) in 4½ ounces of water, filter it, and pour a part into twelve different glasses. To the first six add the re-agents described in par. 563, page 169. Potassa and lime separate the oxide. Carbonate of potassa gives carbonate of lead. The hydrosulphuret of ammonia gives black sulphuret of lead, and is much employed in detecting this metal in solution. All the other substances produce white precipitates.

571. To the seventh glass add sulphuric acid or any sulphate in solution; white sulphate of lead falls. To the eighth add hydrochloric acid or any hydrochlorate; white chloride of lead appears. With the ninth mix a solution of iodide of potassium: yellow iodide of lead is precipitated. To the tenth add a solution of chromate of potassa; yellow chromate of lead is precipitated.

572. In the eleventh put a small fragment of zinc; it takes away all the acetic acid and oxygen, and lead is slowly deposited in crystals. The last experiment may be varied by diluting the solution with an equal bulk of water, placing it in a narrow glass, and suspending the zinc at the top of the solution. The lead appears in an

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359. What corrodes it, or prevents corrosion?
360. What of the salts of lead? experiments.

arborescent form, producing what is commonly termed the *lead tree.*

573. Acetic and nitric acids act most powerfully on lead, corroding it, and forming compounds soluble in water. [The former acid is applied in the form of vapor to sheet lead in the manufacture of *white lead.* an important article of commerce.] Oxide of lead is used in glazing pottery ware, and is often dissolved by vinegar or other acescent substances, which then become poisonous. Sulphureted hydrogen gas alone, or in combination with ammonia, is used to detect lead (570). Waters abounding in carbonic acid corrode lead, and become unfit for daily use when kept in leaden cisterns.

COPPER.

574. Expose copper to a dull red heat for half an hour, allowing the air to play freely upon it, and then plunge it suddenly under water; the oxide formed on the surface is speedily separated, and the metal presents its proper metallic lustre.

575. Put several slips of copper into 2 drachms of nitric acid, diluted with twice the bulk of water. The copper is quickly dissolved, part of the acid communicating oxygen, the rest combining with the oxidated metal.

576. Put a plate of iron into a solution of sulphate of copper (blue vitriol). The copper appears in the metallic form, the iron uniting with all the acid and oxygen previously combined with it.

577 If fragments of zinc, or a few iron nails be boiled with any solution of copper in an acid, the whole of the copper is soon precipitated.

578. Add a little ammonia to a solution of copper; the oxide is immediately precipitated; on adding more, the liquid assumes a deep blue colour, and the oxide is dissolved. Copper and brass vessels (brass consists of copper and zinc) are frequently corroded when incautiously used in some culinary operations; as its solutions are poisonous, liquids suspected to contain it ought to be tested by adding

ammonia to them, observing if a deep blue colour be produced, which indicates the presence of copper.

579. Arrange six glasses, each containing a solution of sulphate of copper, prepared in the same manner as the sulphate of iron solutions described in 563. Add to them the tests directed to be applied to the sulphate of iron; similar changes take place, but the tints are different.

ZINC.

580. Zinc is a brittle metal, having a white colour with a shade of blue.

581. Heat a few fragments of zinc to bright redness in an open fire, or in a crucible. The zinc is soon converted into vapour, and burns with a brilliant flame as it acts on the oxygen of the air.

582. Melt 600 grains of copper in a crucible, heating it to bright redness in a furnace, and covering it with a teaspoonful of salt or charcoal to exclude the air. Add 200 grains of zinc previously well heated, that it may be freed from every trace of moisture, and mix them well by stirring with an iron rod. Brass is formed as the copper and zinc combine. Remove any oxide when it is cold by a file, and the yellow colour of the brass becomes apparent.

583. The hydrochlorate of zinc has been lately used to a great extent by Sir William Burnett for protecting numerous vegetable substances from decay. For this purpose, the substance to be protected, as wood, cordage, or sailcloth, is steeped in a solution, and then dried.

TIN.

584. Tin has a brilliant white appearance when pure, and is malleable and ductile. Heat tin in a crucible; it is soon covered with an infusible oxide.

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361. What is said of copper? its salts.
362. Define zinc, and its combinations.

585. Pour upon tin, in fragments, a little aqueous nitric acid, diluted with an equal bulk of water: the tin quickly attracts oxygen, and assumes the form of a white powder.

BISMUTH.

586. Bismuth is a brittle metal, having a white colour with a shade of red. Heated in a crucible, it oxidates much in the same manner as lead. It is distinguished by its great fusibility, a property which many of its compounds also present.

587. Heat 800 grains of bismuth, with 400 of tin and 400 of lead, in a crucible till they melt. A compound is formed so fusible that it becomes liquid when heated to 204 degrees.

588. Melt half of the above in boiling water, and add 100 grains of mercury; the compound now becomes fluid at 170 degrees. Many toys are made of this composition, which melt when they are put into warm fluids.

ANTIMONY.

589. This is a very brittle metal, having a brilliant white colour and metallic lustre. Mix intimately in a crucible 400 grains of iron-filings and 800 of sulphuret of antimony; heat the mixture to bright redness in a crucible, then add 100 grains of nitre in powder; on breaking the crucible when it is cold, with a hammer, the antimony will be seen below, and a compound of sulphur and iron above. The nitre promotes the separation of the antimony.

590. Mix 600 grains of nitre, 200 of sulphur, and 100 of sulphuret of antimony; place it upon an iron or earthen cup, and apply a lighted match. A brilliant deflagration takes place; the mixture is termed the *blue signal light.* It can be seen at the distance of fifty miles.

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363. What is said of tin?
364. Describe bismuth, and its properties.
365. What of antimony and its uses?

CHROME, MANGANESE, ARSENIC, AND COBALT.

591. CHROME.—The most important compound of this metal is the bichromate of potassa, which is commonly prepared by heating the ore with nitre, when the chrome becomes chromic acid by attracting oxygen from the nitre: it combines at the same time with the potassa, part of which is afterwards withdrawn by another acid.

592. Heat a few grains of the bichromate to redness; part of the chromic acid loses oxygen, and becomes green oxide of chrome.

593. Prepare five glasses, each containing a little of the bichromate in solution.

I. Add to one carbonate of potassa in solution; it combines with the excess of acid, and yellow chromate of potassa is formed.

II. Proceed as in par. 47, page 30.

III. Add nitrate of mercury in solution to the third glass; chromate of mercury falls, in the form of an orange-coloured powder.

IV. Mix a few drops of a solution of nitrate of silver with the bichromate in the next glass. Brick-red chromate of silver is seen.

594. Mix intimately 95 grains of the bichromate with 110 of common salt; heat the mixture in a retort with 2½ drachms by measure of aqueous sulphuric acid. Chlorine and chrome, or oxide of chrome, combine and produce a brilliant ruby-coloured vapour, *chlorochromic acid*, which may be condensed in a receiver; carry off the fumes as the process advances. Pour the product into three wine glasses, and add cautiously a drop of alcohol to one, of aqueous ammonia to the second, and a grain or two of sulphur to the third. In each case, heat and light appear, from the action of the chlorine on the hydrogen of the first two compounds, or on the sulphur, and green oxide of chrome is at the same time seen. These substances should be suspended at the extremity of a long cane, before they are added to the fluid.

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366. Define chrome and cite the experiments.

595. Mangane[illegible] 100 grains of the binoxide (common peroxide [illegible]ganese with 300 of nitre, in a crucible, to redness for half an hour. It attracts oxygen from the nitre. and unites with the potassa; water dissolves it, giving a fine green-coloured solution, which becomes purple and of a pinkish hue as it is merely exposed to the air, or diluted with an additional quantity of water. Hot water induces these changes much more speedily than cold water.

596. Arsenic.—The violent poison known by this name consists of oxygen and the metal arsenic; it may be distinguished by the following characters:—Heat a grain in a dry test-tube; it is volatilized, and condenses on the sides of the tube in crystals, which have a brilliant lustre.

597. Heat a grain in another tube, after mixing it with twice its bulk of charcoal. Metallic arsenic condenses on the side of the tube, presenting a steel-gray lustre.

598. Mix a little with a drop of a solution of nitrate of silver, and add a minute quantity of potassa; yellow-coloured arsenite of copper is seen. Treat another portion in the same way with sulphate of copper; a similar action takes place, and grass-green arsenite of copper appears. Add a little boiling water in both cases, if the proper tint is not seen at first.

599. Cobalt.—Write on paper with a dilute solution of hydrochlorate of cobalt; nothing is observed when it is dry; heat it, and the characters traced with it appear of a fine blue colour. If the solution be mixed previously with common salt, a green tint appears. The colour fades again on cooling.

MERCURY, SILVER; GOLD, AND PLATINUM.

600. Mercury or quicksilver. Boil 10 or 12 grains of mercury in a test-tube, holding it in the flame of a spirit-

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367. Describe manganese, and its chemical changes.
368. Define arsenic, and the experiments with it.
369. What of cobalt?

lamp. It rises in vapour, and condenses in brilliant globules in the upper part of the tube.

601. Heat 20 grains of mercury in a small evaporating basin, with 1 drachm by measure of nitric acid; much gas is evolved; the mercury takes oxygen from part of the acid, and combines with the rest. Heat the liquid till a dry mass appears, and then increase it gently till it becomes of a very deep red. Binoxide of mercury is thus obtained, which brightens as it cools, and presents small crystals. Heat a few grains in a test-tube, placing it in a spirit-lamp; oxygen is expelled, and the mercury volatilized, condensing ultimately, as in 600.

602. Mix 20 grains of mercury with one-third of the acid directed above, dilute it with three times its bulk of water, and allow the action to go on with little heat. A nitrate is formed, in which the mercury has little oxygen combined with it.

603. Heat in a test-tube, as in 600, 20 grains of mercury and 3 grains and one-half of sulphur. They combine, and produce *vermillion*, or *bisulphuret of mercury*, which assumes its usual tint when reduced to powder; it is obtained with a brilliant hue only by slowly or repeatedly subliming it.

604. Heat 20 grains of mercury and 25 of iodine in the same manner; a brilliant yellow biniodide is produced, which soon assumes a scarlet hue.

605. Dissolve a few grains of *bichloride of mercury*, a virulent poison, in an ounce of water, and divide it into four portions. Potassa and lime-water separate binoxide, the mercury deriving oxygen from the water. Iodide of potassium produces biniodide of mercury. Hydrosulphuret of ammonia gives bisulphuret of mercury, dark in colour till it is sublimed.

606. Animal and vegetable matters subject to decay in damp situations, as wood and canvass, are often steeped in a solution of the bichloride to preserve them.

607. Put a piece of tin-foil, two inches long by one broad, upon a sheet of paper; drop a little mercury upon it, spreading it upon the tin with a hare's foot. Cover it with a slip of paper twice its own length, and place over

the paper any plain piece of glass. On drawing out the paper, pressing down the glass all the time, the tin and mercury adhere to the glass, so as to produce a small looking-glass.

608. SILVER.—This metal is distinguished by its pure white colour and brilliant lustre. It is very malleable and ductile.

609. Add silver in fragments to aqueous nitric acid, exposed to heat, and diluted with three times its bulk of water, so long as it is dissolved. Part of the acid is decomposed, oxidating the metal, and the remaining portion combines with the oxide, forming nitrate of silver. Crystals are deposited as the solution cools; when these are fused to expel any adhering water or excess of acid, common *lunar caustic* is procured.

610. Fuse half a grain of nitrate of silver on a slip of glass, heating it by the flame of a lamp. All the nitric acid and oxygen are expelled; metallic silver alone remains.

611. Dissolve 20 grains of nitrate of silver in an ounce of water, to be used as a solution for experiments with silver. Arrange six glasses with water, adding to each a few drops of the solution of silver, and afterwards the following tests in solution:—

612. Potassa separates oxide of silver as an ash-gray powder.

613. Carbonate of potassa precipitates carbonate of silver.

614. Lime precipitates oxide of silver.

615. Hydrochloric acid, chlorine, and common salt, precipitate chloride of silver.

616. Chloride of silver is white and curdy, but assumes a dark colour on exposure to the light.

617. Put a fragment of copper into one glass, of zinc into another, and a few grains of mercury into a third; on covering each with a little of the solution of nitrate of

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370. Describe the experiments with mercury and its various compounds.

371. What of silver and its properties?

372. Repeat the experiments named.

silver, metallic silver soon appears, a corresponding quantity of the other metal which precipitates it being dissolved.

618. Write on a piece of linen with a pen dipped in the solution of the nitrate, and, when dry, immediately spread upon it a solution of potassa or soda. The oxide of silver is left insoluble upon the cloth, and soon darkens in its tint, leaving a permanent mark upon the cloth. A solution of the nitrate forms common marking, or what is termed *indelible* ink. The alkali is used to remove the nitric acid, and prevent the cloth from being corroded. A carbonated alkali, as common soda, is often used instead of the purer alkali; 100 grains may be dissolved for this purpose in an ounce of water.

619. **Gold.**—This metal is distinguished by its malleability and fine yellow colour; it is found principally in a pure form. Gold-leaf is so thin that 282,000 leaves are required to make up the thickness of an inch. In gilded silver-wire, the gold is less than the 3,000,000th part of an inch in thickness. It is not affected by air or oxygen at any temperature, and common acids have no effect upon it.

620. Put four or five gold leaves into an evaporating basin; pour upon them a few drops of nitric and of hydrochloric acids. Chlorine from the hydrochloric acid quickly dissolves the gold. Evaporate the solution to dryness, so as to expel excess of acid; terchloride of gold remains.

621. Dissolve the terchloride in 30 or 40 drops of water. Dip a slip of glass into the solution, and heat it over a lamp; the chlorine is expelled, and metallic gold remains. On looking through the glass, a purple tint is often seen. Write upon the palm of the hand with a pen dipped in a solution of the terchloride; it acquires a purplish tint, which disappears in a few days.

622. Heat a slip of glass in the flame of a lamp, touch powdered borax with it, when it immediately adheres. A

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373. The properties of gold?
374. What experiments and compounds?

drop of the solution is then to be put upon the borax. when it is to be heated by a lamp, taking care not to smoke it. A beautiful ruby-coloured compound appears; metallic gold is afterwards observed, if the heat be continued long.

623. Put three drops of the solution upon paper, and add the following tests in solution.

624. Sulphate of iron, which precipitates metallic gold of a dark colour, being in a minute state of division.

625. Hydrochlorate of tin produces a purple precipitate, containing gold and oxide of tin, and usually termed the *purple precipitate of Cassius.*

626. Hydrosulphuret of ammonia produces a dark coloured sulphuret of gold.

627. *Platinum* is a metal much prized in making crucibles, capsules, and numerous other articles of chemical apparatus, as it is scarcely affected by any ordinary chemical agent, many of which corrode other metals. It is also very infusible, not being melted by the heat of any common furnace.

628. Dissolve five or six grains of platinum wire in a drachm of nitric acid, mixed with an equal bulk of hydrochloric acid. Add more acid if it be required, and evaporate cautiously to dryness. Bichloride of platinum is obtained: dissolve it in one or two drachms of water. Add a solution of iodide of potassium to a part of it; a deep coloured compound immediately appears.

629. Add a solution of hydrochlorate of ammonia; a ternary compound of this substance and the platinum is formed. and is soon precipitated of a yellow colour. Heated to redness in a crucible, every thing is expelled except the metallic platinum; it is not fused. but remains in minute particles, in which condition it absorbs much oxygen from the air, and when hydrogen is directed upon it. a red light is observed, and the hydrogen is soon inflamed.

ALLOYS AND AMALGAMS.

630. *Alloys* are compounds in which metallic bodies are combined solely with each other. They are formed

in general by fusing the least fusible metal in the first instance, and adding the others to it. The term amalgam is usually applied to alloys containing mercury. Some alloys consist of two metals only, but in others a number are combined together.

I. *Brass* = 3 parts copper + 1 zinc.

II. *Dutch gold and pinchbeck* = copper and zinc combined in various proportions, according to the quality required.

III. *Bronze and gun-metal* = 8 or 9 parts copper + 1 tin.

IV. *Bell-metal* = 3 parts copper + 1 tin.

V. *Speculum metal* = 2 parts copper + 1 tin.

VI. *Pewter* = tin, with small portions of other metals.

VII. *Plumbers' solder* = 1 part tin + 2 lead.

VIII. *Tinfoil* = tin + a small portion of lead.

IX. *Fusible alloy* = 8 parts bismuth + 5 lead + 3 tin.

X. *Rose's fusible alloy* = 2 parts bismuth + 1 lead + 1 tin.

XI. *Gold coin* = 11 parts gold + 1 copper.

XII. *Standard silver* = 12 and 1-3d silver + 1 copper.

XIII. *Tinned iron*, or *tin plate*, consists of iron coated on the surface with tin.

631. Many metals may be coated with gold or silver by precipitating the gold and silver upon them from their solutions.

632. *Fluid amalgams* of gold and silver are used for the same purpose; they are spread upon the metals to be coated, and the mercury is expelled afterwards by heat.

633. Eight parts of the fusible alloy + 1 mercury = an amalgam which is fluid at 170 degrees.

634. *Amalgam for the electrical machine* = zinc 1 part + 1 tin + 2 mercury.

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375. What are alloys and amalgams?
376. Name some of them, and the proportions.

CHAPTER XXIV.

ORGANIC CHEMISTRY.

635. *Organic chemistry* signifies the chemical history of the various proximate principles* which have been observed in the animal and vegetable kingdoms, and which are there associated together, so as to produce a peculiar structure, termed *organic*, such as is never seen in any of the products of the mineral kingdom. Gum, sugar, starch, woody fibre, albumen, fibrine, gelatine, and all those numerous substances of which plants and the bodies of animals are composed, constitute those proximate principles which are the products of animated nature. All of them, however, are composed principally of a very few of the same elements.

636. Vegetable substances are composed principally of carbon, oxygen, and hydrogen; nitrogen is more rarely observed in them. Animal matters consist generally of carbon, oxygen, hydrogen, and nitrogen; the presence of nitrogen gives to them many of the more peculiar properties by which they are distinguished from vegetable substances.

637. All animal and vegetable substances are decomposed by heating them in an open fire, burning as their carbon and hydrogen act freely on the oxygen of the air. They leave in general a small quantity of ash, composed either of potassa, various salts containing soda, potassa, or lime, and traces of iron or other metals.

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* [These proximate principles being the product of living laws may be chemically decomposed into their elements by analysis, yet they cannot be reconstructed by synthesis. No chemist has ever been able to make a drop of blood or albumen, gelatine or fibrine, those proximate principles being only generated in living beings by the laws of vitality.]

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377. What is organic chemistry?
378. Name some of the proximate principles?

638. The chemical changes that take place in the animal and vegetable kingdom during life, consist essentially in the transformation of part of the varied materials used as food, so that they become assimilated, and take their place as portions of the living texture, while other matters which may have already occupied a similar station are gradually removed to make way for that arrangement that may at the moment be best adapted for the living frame. Thus, a perpetual accession of new particles and removal of others proceeds steadily and uninterruptedly so long as life is sustained. The precise nature of the chemical changes that occur in most of these cases, is very obscure, and traced with much difficulty, though the general action is understood. Matters forming part of a living system, do not present the same chemical changes that are observed in dead matter; this does not arise from their being one kind of chemical action to which minerals and dead matters are subject, and another for matter endowed with life, but partly from the peculiar circumstances in which they are placed in the living system, preserving them in a particular condition, in the same manner as mineral substances may be exposed to one operation, or protected from the action of particular bodies by peculiar treatment, [but chiefly, because of the laws of vitality which are paramount, modifying and controlling chemical action, rendering it tributary and subordinate to the living organization and functions.]

639. It is curious, however, to observe how speedily any portion of animal or vegetable matter becomes subject to ordinary chemical changes when its vitality is gone, whether this may have ensued in consequence of its having been injured or removed altogether from any connection with the frame to which it was attached, or from the whole body having been deprived of life. A very remarkable illustration of this fact is presented in the bodies of persons or animals who may have been killed suddenly. There,

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379. The difference between plants and animals?

380. The character of the chemical changes in the organic world during life.

381. How modified?

the gastric juice, a peculiar fluid subservient to digestion, which affects the food only during life, instantly attacks the substance of the stomach, when life is extinct, in the same manner as it continues to affect the food itself, corroding it often to such an extent in its most depending part, that it is completely perforated and destroyed by that very agent which it supplies during life for promoting digestion and the nourishment and strength of the system.

640. Again, the examination of the great changes effected within the system while the temperature is comparatively stationary, has taught chemists a very important lesson, namely that great and new changes may probably be effected on all kinds of materials by long exposure to various carefully regulated temperatures: and in modern times, no principle has been applied with more success in preparing different compounds, and in examining generally the products of the animal, vegetable, and mineral kingdoms, than that which we have now mentioned as being dependent on the long-continued application of a fixed and carefully regulated temperature.

641. When heated in vessels so that the air is excluded from them, much carbureted hydrogen gas is evolved; water, tar, and numerous oily or resinous compounds, may also be separated by distillation, and a considerable quantity of charcoal remains. But the precise effects produced are much influenced by the exact degree of temperature to which they are subjected, so that very various products may be obtained from the same materials, according to the degree of heat applied. Changes induced by a temperature comparatively low, and without the separation of carbon, are said to be effected by the *white distillation*, the resulting products being always of a light colour, while part of them are generally converted into vapours which may be separated by distillation. Products obtained by exposing animal or vegetable matters to a high temperature,

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382. What illustration is given?
383. What of the power of temperature?
384. What of the two kinds of distillation?

are said to be formed by *destructive* distillation; they are usually mixed with tar and carbon, which give them a dark appearance.

642. When animal or vegetable substances are combined with various chemical agents, they may be rendered much less prone to putrefaction or decay than they are under ordinary circumstances. This depends in some cases upon a combination being effected between the organic matter and the substance used, while on other occasions they appear to operate principally by excluding the action of atmospheric air. This is particularly observed in many of the processes adopted for curing meat and preserving fruit. Occasionally, however, the principal value of some of the materials used depends on the insolubility of the compounds they form with different animal or vegetable substances that may have been fluid previously, and extremely prone to decomposition. Metallic salts have been very generally used for the purpose of preserving timber in exposed situations, among which the hydrochlorate of zinc, introduced lately by Sir W. Burnett, has been much employed; it is applied in solution, not only to wood, but also to sail-cloth, cordage or other materials, which are steeped in the solution, and subsequently dried. Kreosote, which is powerful in coagulating numerous albuminous compounds, owes its power of preserving various animal substances to the impervious nature of the compound it forms with the albuminous fluids, which would otherwise be prone to putrefaction.

643. The entire exclusion of the air is very favourable for the preservation of numerous animal and vegetable substances from decay; which may apparently be preserved indefinitely, or at least for a series of years, without undergoing any change. This is well illustrated in the various processes introduced of later years for preserving meat, more particularly in those introduced by Mr. Gillon. In the process conducted by Mr. Goldner, the materials being

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385. The effects of chemical agency upon animal and vegetable substances Example.

386. What of the exclusion of the air?

cooked and heated at a temperature elevated moderately above 212 degrees, the atmospheric air is entirely expelled through a small aperture by the steam formed within the tin case in which they are heated, after which all communication with the external atmosphere is intercepted by closing the aperture suddenly with solder, while the steam is still escaping in full force.

644. On board ship, bread that becomes overrun with insects under ordinary circumstances, may be kept indefinitely in air-tight iron tanks without injury. And where the bread has been already injured from the cause now mentioned, the insects are soon destroyed if they be introduced into air-tight tanks, any oxygen necessarily present at first being soon consumed if they are well filled.

645. The greater number of organic products are prone to putrefaction, which proceeds most rapidly at a warm temperature, and when there is abundant access of air and moisture. Excessive heat retards or arrests it altogether, by expelling moisture, and extreme cold produces the same effect, by inducing congelation.

CHAPTER XXV.

VEGETABLE CHEMISTRY.

646. All seeds contain a *germ*, which produces the future plant. *Germination* is the process by which the germ begins to grow from the seed, one part, the *radicle*, descending into the earth and forming the roots, while another, the *plumula*, ascends and produces the stem. When the seed is planted, sugar is formed by the matter around the germ, constituting the first nourishment it re-

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387. What illustrations?
388. What is vegetable chemistry?

ceives. The presence of oxygen is necessary to commence germination, which cannot proceed at a great depth from the surface of the soil in which the seed is placed.

647. *Vegetation* includes all those processes which are necessary to the growth of the plant after germination. By *absorption*, nutritious matters are taken up by the roots and other parts of plants; by *circulation*, the sap is carried to the leaves, where a process similar in some respects to the *respiration* of animals is carried on, though very different in respect to the products evolved,* after which it is conveyed where the different proximate principles are separated from it by the process of *secretion*.

648. Though the minute history of the chemical changes that ensue in the living system in the animal and vegetable kingdoms, has not hitherto been traced, a very great amount of valuable information has been obtained in reference to the nature and properties of the different proximate principles, and the relations which they bear to external agents. The products observed in the vegetable kingdom that have attracted most attention, are described in the succeeding chapters. The following table gives a view of the composition of some of the more important vegetable compounds, which will enable the beginner to become familiar with a few examples, showing the great diversity of compounds that may be formed by a few elements uniting in various proportions.

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* See Respiration of Animals.

389. Define *germ*, *radicle*, *plumula*, &c.
390. Describe the functions of vegetation.

TABLE SHOWING THE COMPOSITION OF DIFFERENT VEGETABLE PRINCIPLES.

Names.	Symbols.	Equivalents.	Component Parts.				
			Carbon.	Oxygen.	Hydrogen.	Nitrogen.	Water of Crystallization.
Oxalic Acid. - -	$\vdots C^2$	36·24	12·24	24			
— — Cryst.	$3\cdot H+C^2$	63.24	12·24	24			27
Acetic Acid,	A or $O^3C^4H^3$	51·48	24·48	24	3		
Tartaric Acid,	T or $O^5C^4H^2$	66·48	24·48	40	2		
— — Cryst.	$\cdot H+O^5C^4H^2$	75·48	24·48	40	2		9
Citric Acid, - -	$O^4C^4H^2$	58·48	24·48	32	2		
— — Cryst.	$2\cdot H+O^4C^4H^2$	76·48	24·48	32	2		18
Benzoic Acid, -	B or $O^3C^{14}H^5$	114·68	85·68	24	5		
Gallic Acid, - -	G or $O^5C^7H^3$	85·84	42·84	40	3		
Succinic Acid, -	S or $O^3C^4H^2$	50·48	24·48	24	2		
Hydrocyanic Acid.	$O,1C^2N$	27·44	12·24	8	1	14·2	
Cyanic Acid, - -	$\cdot C^2N$	26·44	12·24	8		14·2	
Morphia, - - -	$O^6C^{34}H^{18}N$	288·25	208·05	48	18	14·2	
Quina, - - - -	$O^2C^{20}H^{12}N$	164·6	122·4	16	12	14·2	
Cinchonia, - -	$OC^{20}H^{12}N$	156·6	122·4	8	12	14·2	
Strychnia, - - -	$O^3C^{30}H^{16}N$	237·8	183·6	24	16	14 2	
Camphene, - -	$C^{10}H^8$	69·2	61·2		8		
Camphor, - - -	$OC^{10}H^8$	77·2	61·2	8	8		
Benzule, - - -	Bz or $O^2C^{14}H^5$	106·68	85·68	16	5		
Pyroxilic Spirit, -	OCH^2	16·12	6·12	8	2		
Sugar, dry, - -	$O^{10}C^{12}H^{10}$	163.44	73·44	80	10		
Sugar, common, -	$O^{11}C^{12}H^{11}$	172·44	73·44	88	11		
Sugar, starch, -	$O^{14}C^{12}H^{14}$	199·44	73·44	112	14		
Alcohol, - - -	OC^2H^3	21·44	12·24	8	3		
Ether, - - -	$O+C^4H^5$ or $\cdot H+C^4H^4$ or OC^4H^5	37·48	24·48	8	5		
Hyponitrous Ether,	$\vdots N+OC^4H^5$	75·68	24·48	32	5	14·2	
Etherine, - - -	C^4H^4	28·48	24·48		4		
Aldehyde, - - -	OC^2H^2	22·24	12·24	8	2		

CHAPTER XXVI.

VEGETABLE ACIDS AND ALKALIES.

649. *Oxalic acid* is very soluble in water; crystallizes with facility when its watery solution is concentrated. It is very acid, and a virulent poison. Employed in polish-

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391 Name some of the proximate principles of vegetables, and their composition.

ing brass, and in cleaning leather. It is much used as a test of lime, forming a very insoluble compound with it. It may be obtained from the juices of various plants, but is formed in general, artificially, by heating nitric acid with impure sugar unfit for ordinary purposes, or by heating various vegetable matters, as sawdust, with lime, to a temperature between 400 and 500 degrees, removing afterwards the lime by the action of sulphuric acid.

650. *Acetic acid* is the acid of vinegar, and is formed also in large quantity by heating wood, excluding the air; obtained from this source, it is often termed pyroligneous acid. In a concentrated form it has a very pungent and fragrant odour, and is then used for vinegarettes.

651. Take 1 ounce of vinegar by measure, mix it with a little vegetable blue, which is reddened, and add to the solution bicarbonate of potassa in fine powder till the acetic acid is neutralized, the blue tint being restored. Note the quantity of bicarbonate employed, and calculate the quantity of acetic acid in the solution, 101 grains of the bicarbonate containing a sufficient quantity of potassa to neutralize 51 of real acetic acid.

652. Acetic acid corrodes many metals; with oxide of lead it forms the acetate or sugar of lead. With oxide of copper verdigris is produced, which is an acetate of copper.

653. *Tartaric acid* is procured from cream of tartar. It is not volatile like the acetic acid, and is decomposed when heated. One equivalent of water is always combined with it, in the condition in which it is obtained; 75·48 grains of the crystals are always used where 66·48 of the acid are required.

654. Dissolve 75 grains of crystallized tartaric acid in a tumbler one-third full of water, and dissolve 101 grains of bicarbonate of potassa in another, adding a little sugar and ginger or cinnamon powder to the mixture, if required to communicate any flavour to it. On mixing the solutions, an effervescing draught is formed, from which the

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392. Describe oxalic acid and its uses.
393. How prepared?
394. What of vinegar and its compounds.
395. Describe tartaric acid and its combinations.

carbonic acid escapes quickly; tartrate of potassa being formed in solution, and carbonic acid gas rapidly disengaged. For an ordinary draught, half the above quantity of materials is generally employed, a few grains of acid being added in excess, to communicate an acidulous taste.

655. Add a few drops of a solution of tartaric acid to a concentrated solution of carbonate of potassa, till a neutral tartrate of potassa is formed; it is very soluble in water. Add afterwards more tartaric acid till the solution is very acid; cream of tartar (bitartrate of potassa) falls down in small crystalline grains.

656. *Citric acid* is obtained from the juice of the lime and of the lemon. It is soluble in water, crystallizable, easily decomposed by heat, and, when crystallized, may be kept for any length of time, not being apt to decompose like the juice from which it is separated.

657. *Malic acid*, termed also *sorbic acid*, is found in the juice of the apple and of other vegetable fruits.

658. *Gallic acid* is obtained from gall nuts, but may be procured also from numerous other vegetable substances, as the bark of the oak and the tea leaf. It is particularly distinguished by producing, with peroxide of iron, when these substances meet each other in solution, a dark-coloured compound, which forms the colouring matter of common ink. The colouring matter of ink may, accordingly, be destroyed by any substance which acts either on the gallic acid or on the peroxide of iron. Acids, particularly sulphuric, nitric, hydrochloric, and oxalic acid, destroy the colour of ink by combining with the peroxide of iron and liberating the gallic acid. Alkalies remove the gallic acid, and leave the oxide of iron. A solution of gallic acid often restores faded ink by acting on the iron. Chlorine appears to act on the gallic acid and decompose it, while another portion combines with the iron. Oxalic acid, and other vegetable acids, remove the colour of ink, without destroying the texture of paper or other organic matters, in the same manner as mineral acids.

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396. What of citric acid?
397. Of malic acid.
398. Describe gallic acid and its uses.

659. *Succinic acid* is procured by sublimation from amber. It is much employed, when combined with ammonia, in precipitating peroxide of iron.

660. Put 20 or 30 grains of *benzoic acid* into a Florence flask, and expose it very slowly and cautiously to the heat of a lamp; it is soon melted, and converted into vapour, condensing in beautiful crystals upon the upper part of the flask, if the heat be not too great. If a piece of thread, or any solid substance, be suspended in the interior of the flask, the crystals collect very beautifully upon it.

661. *Prussic* or *hydrocyanic acid* exists in minute quantity in a number of flowers and fruits, communicating to them a very rich and agreeable flavour, as in the flower of the hawthorn, in the peach, and in the almond. It contains no oxygen, and is composed entirely of cyanogen and hydrogen; 26·44 parts of cyanogen contain 12·24 of carbon and 14·2 of nitrogen. *Symb.* CN^2. With 1 of hydrogen, 26·44 of cyanogen produce 27·44 of prussic acid. *Symb.* HC^2N. It is distinguished by its great power, when in a concentrated form, in affecting the animal economy, a few drops being quite sufficient, when laid upon the tongue of a large dog, to produce instant death, almost with the rapidity of lightning. Laurel water, noyau, and many other liquids, contain a portion, and sometimes give rise to fatal effects, when the prussic acid is present in too large quantity.

662. No fact appears more singular at first, than that a principle of such powerful activity in reference to the animal economy should consist of the very same elements as are consumed every day in our food; but chemistry abounds in facts such as these, as is observed, for instance, in the compounds of oxygen and nitrogen, these elements constituting in one proportion the air that we breathe, and in another the corrosive nitric acid or aquafortis.

663. Prussic acid is usually prepared from ferrocyanate

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399. Of succinic acid.
400. What of benzoic acid?
401. Describe prussic acid and its properties.
402. What is wonderful in its composition?

of potassa, a yellow-coloured salt, which is formed on the large scale by heating animal matter with potashes and iron. This salt is mixed with half its weight of sulphuric acid, previously diluted with three or four times its bulk of water, and allowed to cool before it is poured upon the salt in powder; the acid uniting with the potassa and the prussic acid, which is united with iron in the salt, may be condensed in a receiver in combination with the water which distils along with it. The acid should be prepared only in small quantity, and always diluted with water, by those not accustomed to operate with it, so as to prevent any risk of accident. The receiver ought to be kept very cold. Five or six grains of the salt are quite sufficient to give enough of the diluted acid to allow its flavour, so similar to that of the hawthorn, to be recognised.

664. As a chemical agent, hydrocyanic acid is extremely feeble, and very prone to decomposition. Strong and pure acid begins to be decomposed when subjected to the action of light, and, in warm weather, very soon after it has been prepared.

665. To detect hydrocyanic acid in fluids suspected to contain it, the following process may be adopted. Distil the suspected liquid, after adding a little acetic acid to combine with any alkali that may be present. Add to the product salts containing the oxide and peroxide of iron; liberate these oxides by the addition of potassa, when prussian blue is formed, if prussic acid be present. A few drops of hydrochloric acid render the blue more distinct, by dissolving any excess of oxide of iron.

666. *Cyanogen* may be procured by heating the bicyanide of mercury in a glass or iron tube. It is a pungent suffocating gas, very inflammable, and burns with a purple-coloured flame.

667. *Cyanic acid* is composed of cyanogen and oxygen.

668. *Fulminic acid* is considered isomeric with cyanic acid. It is formed when silver or mercury is dissolved in nitric acid, and mixed subsequently, while still warm,

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403. How is it prepared?
404. What are the tests?
405. Define cyanogen, cyanic, and fulminic acids.

with alcohol. The nitrogen and oxygen are supplied by the acid, and the carbon by the alcohol. The fulminic acid forms insoluble compounds with silver and mercury, which explode with great violence when heated, and also by friction or percussion. They ought to be prepared only in very small quantities at a time, and with the utmost caution.

669. *Vegetable alkalies.*—A number of compounds, called vegetable alkalies, have been discovered in many of the more important medicinal substances obtained from the vegetable kingdom; in these the medicinal properties of the substances from which they are extracted are found more particularly to reside. *Morphia* is the name of the most important vegetable alkali procured from opium. *Quina* and *cinchonia* are procured from Peruvian bark. *Strychnia* is obtained from *nux vomica*, and *veratria* from *white hellebore.* All these substances, and many others, are termed vegetable alkalies, and sometimes alkaloids, as they combine with acids, neutralize them, and form salts, in the same manner as other alkalies. They are composed of the usual elements of vegetable matter, but contain also a considerable quantity of nitrogen.

CHAPTER XXVII.

OILY AND RESINOUS SUBSTANCES.

670. All oily and resinous substances are composed, in general, of about 80 per cent. of carbon, 11 or 12 of hydrogen, and 8 or 9 of oxygen; some contain no oxygen, as camphene, commonly called the spirit of turpentine. Exposed to the air, on any extensive surface, they are apt to imbibe oxygen slowly; and some fixed oils, even at natural temperatures, gradually become warm under these

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406. Name and define the vegetable alkalies?
407. The composition of oils and resins.

circumstances, and burst ultimately into flame, sometimes in a few days, but often not till weeks or months have elapsed. Numerous fires have been traced to the spontaneous inflammation of oil spread upon tow or cotton.

671. *Volatile oils* rise in vapour at the temperature of boiling water; they burn in general with much smoke, and are easily inflamed.

672. Put an ounce of cinnamon bark in fragments into a retort; cover it with water, and distil a portion of the water into a receiver; a portion of volatile oil, having the odour of the cinnamon bark, rises along with it, and renders it milky as it condenses in the receiver.

673. Pour a few drops of oil of turpentine upon a piece of paper, and heat it gently before the fire, or over a lamp, at a distance from the flame. It is soon entirely dissipated, leaving no greasy stain upon the paper.

674. Dip a piece of paper in oil of turpentine, put upon it a grain of chlorate of potassa in powder, and touch it with a drop of aqueous sulphuric acid; peroxide of chlorine is immediately liberated, and inflames the turpentine.

675. Put two drachms by measure of oil of turpentine into any cup or basin placed in the open air, or at a large ventilator. Put into a glass, tied to the end of a long stick, four drachms by measure of strong aqueous nitric acid and one of aqueous sulphuric acid, taking care that there is no turpentine in the measure employed. Hold the mixture as far away from the face as can be done conveniently, and pour it upon the oil of turpentine; much oxygen is immediately communicated to it, and the turpentine is inflamed with explosive violence.

676. *Fixed oils* are frequently obtained by expression; they are thicker than volatile oils, and unctuous to the touch, and require a temperature about 600 degrees to convert them into vapour. They may be regarded generally as compounds of two principles, *Elain*, or the more fluid portion, and *Stearin*, the more solid part, which freezes in cold weather before the elain. When the oil is

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* 408. Explain spontaneous inflammation.
409. What of volatile oils?—experiments.

boiled with potassa or soda in solution, soap is formed, and a substance having a sweet taste is separated, which is usually termed *glycerine.*

677. Heat a few drops of any fixed oil upon paper; it is not volatilized except by a heat sufficient to decompose the paper.

678. Boil soft soap in twice its bulk of spirit of wine, filtering the solution if it be not transparent.

679. Add a portion to common water; if very pure, only a slight opalescence is observed.

680. Add a little of the solution of hydrochlorate or sulphate of lime to water, and mix with it a portion of the solution of soap; the acid unites with the alkali of the soap, and remains in solution; a curdy precipitate, consisting of the earthy and oily matter of the soap, is separated.

681. To another solution of the hydrochlorate or sulphate of lime, as in 680, add carbonate of potassa, or of soda, so long as any precipitate is formed. The acid of the earthy salt unites with the alkali of the carbonate, and the lime and carbonic acid fall down as an insoluble carbonate. Add the solution of soap to the liquid in this condition; it is not decomposed; the acid of the earthy salt is already combined with alkali, and the earthy matter has been precipitated, so as to be incapable of affecting the oily or fatty matter.

682. Dissolve 10 or 20 grains of *resin* in three or four times its bulk of alcohol. Pour the solution into a large quantity of water; the alcohol unites with the water, and the resin is separated.

683. Perform a similar experiment, using *camphor* instead of resin; it is dissolved and precipitated in the same manner as the resin.

684. Heat a few grains of camphor in a tube by a small lamp. It soon melts, produces a transparent fluid, which is quickly volatilized, and condenses in a solid form in the upper part of the tube.

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410. What of fixed oils?
411. Define elain, stearin, and glycerine.
412. What experiments?

685. Put an ounce of *wax* into a teacup or evaporating basin; melt it by placing it in boiling water, preventing any from mixing with the wax. Untwist a piece of cord, and dip the separate parts into the wax; cut them into lengths of 6 or 8 inches, to be used as matches in applying a light in chemical experiments.

686. *Benzule* is the name applied to a compound which forms the basis of several vegetable substances. Benzoic acid is a compound of benzule and oxygen.

687. *Balsams* are viscid liquids or solids procured from different vegetables.

688. *Amber* is considered to have been a balsam originally, and to have become subsequently solid.

689. *Gum resins* are concreted vegetable juices, such as gamboge and guiac, which contain various vegetable principles.

690. *Caoutchouc*, or *India rubber* is the concrete juice of the *ficus elastica* and some other trees. It is soluble in spirit of turpentine, naphtha, ether, and in the fluid it affords by destructive distillation. Its solution in naphtha, thickened and made to resemble a paste, forms the material employed in preparing waterproof cloth, according to Mackintosh's patent.

PRODUCTS OF DESTRUCTIVE DISTILLATION.

691. When vegetable or animal substances are heated to a high temperature, all access of atmospheric air being excluded, numerous compounds are formed, varying greatly according to the materials from which they are obtained, and the temperature to which they may have been subjected. Among these, the following are the most important:—

692. *Tar* is the dark-coloured mixture of oily and resinous substances, with water and acetic acid, which is extracted from the fir by the application of heat, care being taken to prevent combustion. Coal tar is similar to wood tar in its general appearance and properties, but differs

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413. Define benzule, amber, gum resins, and caoutchouc.
414. What of destructive distillation?

from it in many details; it is in particular very alkaline, from the ammonia associated with the water. All tarry substances, when exposed to a gradually increasing heat, lose all the water they contain, and other products associated with it, and a variety of oily products, more or less volatile; a resinous solid remaining, termed *pitch*, which is hard and brittle, if much oil shall have been removed, and soft and unctuous should a small portion only have been expelled.

693. *Pyroxilic Spirit* is the name applied to a clear and colourless fluid which is formed by the destructive distillation of wood. It resembles alcohol in the flame with which it burns, and is often used as a substitute for it in spirit lamps. It has a peculiar odour, and burns with a smokeless flame.

694. *Paraffine* is an inflammable solid, which has been procured by distillation from the tar of beechwood, and from certain varieties of petroleum. It is white, tasteless, inodorous, soluble in alcohol, turpentine, and naphtha. It burns brilliantly and without smoke, and is not decomposed by the action of acids, alkalies, and other powerful chemical agents.

695. *Eupion* is the name given to a volatile oil which is obtained by distillation from the tar of animal matters.

696. *Kreosote* is a volatile liquid which has been obtained both from wood and coal tar. Its more characteristic property is its power in coagulating albumen. Its odour is similar to smoked meat, in which the kreosote is considered to form a compound with the albuminous materials. It is soluble in alcohol, ether, naphtha, and acetic acid. Water mixed with it acquires its taste and odour. In a concentrated form it is used in toothache, coagulating albuminous substances, and protecting the nerve from the immediate action of the air, by the dense compounds formed upon it.

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415. Define tar.
416. Define pitch, pyroxilic spirit, paraffine, eupion, and kreosote.

CHAPTER XXVIII.

LIGNIN, GUM, STARCH AND GLUTEN.

697. *Lignin* is the term applied to woody fibre. It is composed of the usual elements of vegetable matter, but contains also minute quantities of potassa and various salts. Mix a few chips of wood with aqueous sulphuric acid. It is blackened, charcoal being separated as it is decomposed by the sulphuric acid ; sulphurous acid and other gases are evolved.

698. *Gum* is a term applied to several vegetable products, of which gum-arabic is the most important. Dissolve *gum-arabic* in water, after reducing it to powder placing it in a flask or cup heated by immersing it in boiling water. Mix a portion of the solution with an equal bulk of alcohol; the water unites with the alcohol, and the gum is separated.

699. *Cherry-tree gum* is similar in many respects to gum arabic, but is insoluble in cold water.

700. *Pectin* is the term applied to the gelatinous matter which abounds in numerous fruits. It forms a mucilage with water, which is less adhesive than that of gum.

701. *Tannin* is a peculiar principle found abundantly in the vegetable kingdom. It is solid, has an astringent taste, is colourless and inodorous, is soluble in water, alcohol, and ether, and gives a bluish-black precipitate with salts of iron. It resembles gallic acid in several respects, but is distinguished from it by precipitating gelatine.

702. *Vegetable albumen* bears a considerable resemblance to animal albumen, and is coagulated by heat. It

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417. What of lignin and gum ?
418. What of pectin, tannin, and vegetable albumen ?

is often obtained in the solid form, as in the seed of the sweet and bitter almond, and in other fruits.

703. Grate down several potatoes in a basin, covering them with water, and stirring the mixture for a little time; the *starch* which they contain separates from the fibrous matter, and may be seen at the bottom of the mass, being heavier than water, and insoluble in it when cold.

704. Mix starch with cold water, and then pour boiling water upon it; a strong gelatinous mass is formed, if too much water be not poured upon it. It is very nutritious. *Sago*, *tapioca*, *arrow-root*, and *potato flour*, are all composed of starch.

705. Mix a table-spoonful of wheaten flour with water, so as to produce a stiff dough. Spread it upon the palm of the left hand, hold it over a basin of cold water, and with the right hand pour water upon it so long as a milky fluid appears exuding from it, pressing it gently from time to time with the finger. Flour consists principally of starch and gluten mixed with gum and sugar. The water dissolves the gum and sugar; the starch is carried away mechanically suspended by the water, and *gluten* remains on the hand. If the flour be of good quality, about one-third of its weight of gluten is usually obtained. Flour is often sold of such indifferent quality that little gluten is procured from it. Gluten is the most nutritious part of flour, and forms the numerous little cells that appear in fermented bread, as gas and vapour rise in the substance of the dough. It contains nitrogen along with carbon, oxygen, and hydrogen, resembling animal matter in its composition.

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419. What articles are made of starch?
420. How is gluten prepared, and its use?

CHAPTER XXIX.

VEGETABLE COLOURING MATTER.

706. Numerous proximate principles are familiarly known which are particularly distinguished by their colour Each of these is to be regarded as a distinct compound, of which its peculiar colour is only one of numerous properties which it may present. It is accordingly subject to all the usual chemical changes of which colouring matter is susceptible. It may be separated from other materials; it may be decomposed, and deprived consequently of its colour; it may be formed again by new arrangements in some cases, when its colour is restored; it may be combined chemically with various bodies, acquiring a new colour, or becoming colourless, according to the nature of the substance with which it is associated.

707. The art of *bleaching* consists in depriving the substances that are bleached of any colour that they may possess, and also of any impurities with which they may be stained. Chlorine, acids, and alkalies, are the principal agents used for this purpose, the former destroying all animal and vegetable colouring matter, while the others, from their extensive chemical agency, act powerfully upon numerous substances that may be associated with them.

708. The art of dyeing consists in communicating to cloth or other substances the various tints that may be required, and is founded upon the chemical attraction that subsists between colouring matters and those to which they are applied. Some colouring matters, as indigo, if merely dissolved, and brought in contact when in solution with cloth, leave the materials composing the solution, and combine with the cloth; such colouring matters have a strong attraction for cloth, and are usually termed *sub-*

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421. What of vegetable colouring matter?
422. Explain the art of bleaching and dyeing.

stantive colouring matters. Others, again, having a feeble attraction for cloth, may still be combined with it in a comparatively permanent manner by the addition of various metallic oxides, earths, or other chemical agents; all of which unite together so as to form one compound. In such cases the chemical agent employed, which is usually termed a *mordant* or *basis*, is combined with the cloth before the colouring matter is applied; colouring matters used in this manner are usually termed *adjective colouring matters.*

709. *Calico-printing* is a kind of topical dyeing, by which the colouring matter, or the mordant that fixes it, or both, are applied only to certain parts of the cloth, so as to present a pattern. Sometimes wooden blocks, having patterns cut on them, are used for this purpose; these being applied with a light touch to a thick mixture of the materials used, so that they are received by the pattern in the same manner as ink is received by types. On other occasions, the whole cloth is dyed in the first instance, and a white figure produced subsequently by applying the pattern after it shall have received any materials that must decompose, dissolve, or withdraw the colouring matter wherever it touches the cloth. If the mordant be withdrawn by any other chemical agent, that alone is sufficient to enable the colouring matter to be discharged with facility.

710. *Chromule* is a term applied to various coloured principles that may be obtained from the leaves and flowers of plants.

711. *Chlorophyle* is the term applied to the green colouring matter of the leaves of plants.

712. *Chromogen* signifies a matter that has no colour in itself, but which may still be considered as a basis of colouring matter, as, by the action of other bodies, colour may be developed in it. If water containing sulphurous acid be added to the colouring matter of common coloured cabbage in solution, it decomposes it, and a colourless com-

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423. Define the terms in italics.
424. What of calico-printing?

pound results. The colouring matter is reduced to the state of *a chromogen.* But if a portion of the colourless compound be mixed with a little sulphuric acid, a brilliant red tint appears. If ammonia, or any other common alkali be added to a second portion of the colourless liquid, a fine green appears.

713. *Erithrogen* is the term applied to that variety of chromogen which becomes red with acids. The term *xanthogen* is applied to those that become yellow by the action of alkalies.

714. Cut a common red cabbage into small pieces, and boil it for a short time with no more water than is required to cover it. Use the solution procured in this manner, or by simply infusing the cut cabbage in boiling water, as the *cabbage* or *vegetable blue* so often referred to in the preceding pages.

715. Dip into the solution a number of slips of paper, four or six inches square; keep them there till they imbibe some colouring matter, and then dry them, excluding them afterwards from the action of the light, until they are required for use. Cut off small slips, which may be touched with a minute quantity of any solution, to be tested so as to indicate the presence of acid or alkali, as they are reddened by one, and turned to a green by the other.

716. Dilute a solution of the vegetable blue, and try alternately the action of acids and alkalies upon it. Acids render it red; alkalies turn it to a green.

717. Boil litmus in five or six times its bulk of water; prepare test papers with the solution as in 715. They are reddened by acids, but not turned to a green by alkalies.

718. Pour upon a table-spoonful of turmeric placed upon a common plate three or four times its bulk of boiling water, and prepare turmeric test papers as in 715. They are of a fine yellow, and become reddish-brown by alkalies, but are not affected by acids.

719. Add a little alum in solution to a dilute solution

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425. Define the italicised terms, and name the experiments

of litmus in a jar or flask; mix a little potassa with the liquid till the alumina appears, which combines with the colouring matter as it is precipitated.

720. Dip a piece of cotton cloth into a diluted solution of sulphate of iron, and allow it to dry; immerse it afterwards in an infusion of galls, containing gallic acid; it unites with the iron, and the cloth is dyed of a bluish-black colour.

721. Mix a little of the solution of the sulphate of iron with paste, spread it very thin upon cloth, and take up a little by pressing upon it any stamp or block of wood with a pattern cut upon it, which may be applied many successive times to different parts of the cloth if required; any plain piece of wood will do, if no pattern can be made. Dry it, immerse it in a little aqueous ammonia diluted with much water; the acid is removed, and the pattern appears on the cloth in the form of oxide of iron. Run a little water upon it, and pour upon one portion the infusion of galls. A black pattern is now seen upon a white ground. Put another portion into a basin of water, to which a few drops of ferro-cyanate of potassa in solution and aqueous nitric acid shall have been added. A blue pattern is now observed.

722. Put a number of flowers of any colour, and also several green leaves, into a vase of chlorine; all of them are quickly blanched.

723. Put a hank of unbleached yarn, and a number of strips of different coloured cloths, dyed with animal or vegetable colouring matter, into a solution of chlorine in water. They are all soon bleached by the powerful action of the chlorine. Similar experiments may be tried by adding a solution of chlorine to solutions of colouring matter in water. Chloride of lime dissolved in water may be substituted for chlorine, adding a few drops of acid.

724. Put several flowers into a large glass jar, and inflame a little sulphur in a small metallic cup placed within the jar. The sulphurous acid produced by the combus-

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426. Explain the several experiments.

tion of the sulphur blanches a number of flowers. The purple grape hyacinth, the blue crocus, the violet, and many other blue flowers, do well for this experiment; the first is the best.

725. Hold some of the blanched flowers in vapours of hydrochloric acid gas, produced by pouring aqueous sulphuric acid on common salt; the acid, acting on the base of the colouring matter, produces a red tint.

726. Put another portion of the blanched flowers into a jar containing a very little strong aqueous ammonia; the vapour escaping from it turns them to a fine green.

CHAPTER XXX.

SUGAR—VINOUS FERMENTATION—ALCOHOL—ETHER.

727. Sugar is a vegetable principle which is capable of affording a great diversity of products, more particularly when subjected to those changes that accompany the vinous fermentation, a process that consists essentially in the decomposition of sugar, and in the production of alcohol and carbonic acid.

728. *Sugar* is solid, white, and inodorous when pure, and does not deliquesce on exposure to the air. It is soluble in water and alcohol, and combines with alkalies, earths, and metallic oxides. By the strong acids it is decomposed. Sugar is procured principally from the juice of the sugar-cane, which may be regarded as an impure solution of sugar. [Large quantities of sugar are made from the sap of the maple trees of America, and it may also be obtained from numerous vegetables.] Acids which it contains are neutralized by lime, and numerous impurities are removed as the juice is boiled. The solution,

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427. What is sugar and the vinous fermentation?

after concentration, gives raw sugar on cooling, from which the concentrated syrup termed *molasses* is then drained. By repeated solution, filtration, and crystallization, the sugar is ultimately rendered of a pure white colour; animal charcoal is employed to a great extent in this process to destroy colouring matters, and albumen to coagulate and entangle impurities.

729. Sugar presents a great variety of appearances in its raw state, according to the strength and purity of the solution from which it is deposited. Its texture and appearance also are very various when fused, crystallized slowly, or combined with various proportions of water, colouring matter, or other materials.

730. VINOUS FERMENTATION.—The term fermentation is used generally to signify any of those changes that are induced spontaneously in animal or vegetable matters by the reaction of their elements, and vinous fermentation constitutes that variety in which alcohol is produced by the decomposition of sugar. Vegetable juices containing sugar, or a solution of pure sugar in water, when exposed to a temperature between 60 and 70 degrees, soon undergo the vinous fermentation, if a portion of yeast shall have been added previously. This substance is the flocculent matter that is formed during fermentations, and though not absolutely essential to, is particularly distinguished by its power of promoting the vinous fermentation. It bears a considerable resemblance to gluten in some of its properties.

731. During vinous fermentation, every 45 grains of sugar decomposed give (omitting fractions) 22 of carbonic acid and 23 of alcohol. In numerous instances, the fermentation is checked before all the sugar is decomposed, and then a sweet compound is produced, which varies in its qualities according to the amount of carbonic acid retained, and the variety of mucilaginous and other matters that may be associated with the alcohol and water of the

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428. The properties of sugar.
429. The production of alcohol.
430. The proportions of decomposition of sugar.
431. The ratio of alcohol in liquors.

original juice or solution employed, more particularly volatile oils, astringent matter, and colouring matter.

732. The stronger wines have been said to contain 25 per cent. of alcohol, and others from 12 to 18, while ale, porter, cider, and perry, contain from 4 to 10 per cent. These estimates are now considered to be rather high, according to some recent experiments.

733. *Alcohol* is a transparent, colourless liquid. It boils at 173·5, when its specific gravity is ·810. It is inflammable and burns with a pale flame; the products of combustion are water and carbonic acid. It dissolves numerous salts. and also resins, camphor, and volatile oils. It combines with water in every proportion, and the amount associated with it is estimated by ascertaining its specific gravity; the less its specific gravity, the smaller is the proportion of water combined with it. The following table shows the specific gravity of various combina-

TABLE OF THE SPECIFIC GRAVITY OF DIFFERENT COMBINATIONS OF ALCOHOL AND WATER, FROM THE RECORDS OF SCIENCE.

Atoms of Alcohol.	Atoms of Water.	Weight of Alcohol.	Weight of Water.	Specific Gravity of Mixture.
1	0	23	0	·79460
4	1	92	9	·81793
3	1	69	9	·82598
2	1	46	9	·83843
1	1	23	9	·86726
1	2	23	18	·90420
1	3	23	27	·92662
1	4	23	36	·94118
1	5	23	45	·95090
1	6	23	54	·95763
1	7	23	63	·96243
1	8	23	72	·96597
1	9	23	81	·96871
1	10	23	90	·97092

432. Define alcohol and its properties.

tions of water and alcohol. The specific gravity is ascertained with exact accuracy only by instruments made for the purpose. By weighing first the amount of water, and subsequently the amount of the alcohol under examination, which any small stoppered phial contains when quite full, in a bottle previously washed and dried, and maintaining it with the greatest care, during the progress of the experiment, at a particular temperature, namely, 60 degrees, its value may be ascertained. Or allowance may be made for the temperature, whether above or below 60 degrees, by referring to scales which have been constructed for this purpose.

734. Alcohol is prepared by distillation from wine, ale, porter, the fermented infusion of malt, or other materials prepared expressly for affording this substance in a concentrated form. Brandy is the product obtained at first from wine, whisky from the fermented infusion of malt, and rum from the fluid obtained by the fermentation of molasses, or other impure solutions of sugar, after diluting them with water.

735. From these distilled liquids a stronger spirit, termed *spirit of wine*, is prepared by a second distillation, and *rectified spirit of wine* is usually the product of a third distillation. Alcohol, absolutely free from water, is procured solely by treating common alcohol with chloride of calcium, lime or other materials which have a powerful attraction for water, separating the alcohol carefully by distillation.

736. *Ethers* are very volatile, inflammable, and fragrant compounds, which are usually obtained by the action of acids with alcohol. Sulphuric ether is formed by mixing equal weights of sulphuric acid and alcohol, when the ether is formed on the application of heat, and may be separated by distillation. Nitric, called also hyponitrous ether, may be formed on the same principle; but the materials must be mingled with extreme precaution, and by

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433. What of the specific gravity?
434. Alcohol by distillation, its sources and products.

peculiar arrangements, otherwise violent and dangerous explosions are apt to take place.

737. *Aldehyde* is the term applied to a compound obtained from alcohol, by removing part of the hydrogen which it contains.

CHAPTER XXXI.

ANIMAL SUBSTANCES.

738. In the animal kingdom, nitrogen, an element that appears rarely, or, at all events, only in minute quantity, in the vegetable kingdom, is an abundant element, particularly in the more important animal proximate principles, albumen, fibrine, and gelatine, of which it forms from 15 to 19 per cent. The presence of this element in numerous animal products, is the cause of the principal peculiarities which they present, rendering them much more prone to decomposition than vegetable substances, and leading to the production of ammonia, and other compounds, during the progress of putrefaction, which are more rarely evolved from vegetable substances.

739. Animal substances, as they are met with in the living frame, present numerous peculiarities in their physical characters, which cannot be traced after death, these being in part dependent upon the vital fluids circulating within them, the temperature at which they are maintained and other circumstances connected with the living system to which they may be attached. These all tend to produce a peculiar series of changes, which cannot be imitated after death, and accordingly, in experiments with all animal proximate principles, they must be regarded as

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435. What of ethers and aldehyde?
436. The proportion of nitrogen in animal substances.
437. Difference between living and dead matter.
438. Products of animal putrefaction.

being placed in a position essentially different from that in which they are observed during life—as different as the changes that ensue in the living frame are from those that are observed to ensue after death.

740. The products of the putrefaction of animal matter are carbonic acid, water, ammonia, and carbureted hydrogen gases, which are generally mixed with various proportions of phosphureted and sulphureted hydrogen gases. At very high and low temperatures putrefaction is arrested. *Adipocire* is the term applied to a very imperfect saponaceous compound, into which animal matters, excepting bone, are often converted, when the air has imperfect access, or when water is constantly in contact with them.

741. Fibrine, albumen, gelatine, oily, and fatty matters, and bone, constitute the more abundant proximate principles in the animal kingdom.

742. *Fibrine* constitutes the solid part of the common muscular fibre, and forms also a part of the blood It is insoluble in water and alcohol.

743. *Albumen* is found in numerous fluids, as in the blood and in the white of the egg, and is particularly distinguished by the facility with which it is coagulated by the action of heat, acids, alcohol, tannin, and numerous salts.

744. *Gelatine* is soluble in water, and its solution is not coagulated by heat, but gelatinizes on cooling, if sufficiently concentrated. It is precipitated by tannin. Ordinary leather consists of gelatine, combined with tannin, or other substances.

745. *Osmazome* is the term applied to a peculiar principle, soluble both in water and alcohol; it is considered to impart to broth its more peculiar flavour.

746. *Bones* consist principally of earthy matter, and contain about 33 per cent. of animal matter. If bone be placed for a considerable time in diluted hydrochloric acid, the animal matter is left, and the earthy matter dis-

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439. Define adipocire, fibrine, albumen.
440. Define gelatine, osmazome, and bones.

solved. If bone be burned in an open fire, the animal matter is consumed, and the earthy matter appears. If bone be heated, and the air be excluded, tar and inflammable gases are evolved, and animal charcoal is left, which is mixed with the earthy matter of the bone.

RESPIRATION.

747. Respiration consists in the inspiration and expiration of air, which acts upon the dark-coloured blood in the lungs, gives it a brilliant florid red colour, and renews it continually in its qualities, so as to adopt it for the various purposes for which it is required in the living body.

748. If we suppose 16 or 17 respirations to take place every minute, we may be allowed to estimate that man respires, on an average, 1000 times an hour, or draws upon the atmosphere, that great magazine of oxygen, no less than 24,000 times every day and night for nourishment and support, without which his existence could not be prolonged even for a few minutes.

749. The great changes effected in the air are the removal of a part of its oxygen, which is replaced by carbonic acid gas, being thus vitiated in such a manner, and rendered so unfit for respiration, as to prove fatal to any one who might continue to respire for a length of time the same portion of air.

750. Blow through a glass tube into water tinged with litmus. The carbonic acid reddens the litmus.

751. Blow in the same manner into lime-water; carbonate of lime is quickly deposited.

752. Blow into a small flask with a tube, expelling as much air as possible from the lungs, and immediately introduce a lighted suspended candle; it is extinguished.

753. If we assume as an average that between five and six ounces of carbon are consumed daily in the production of carbonic acid, then three individuals will evolve carbonic acid containing one pound of carbon.

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441. What is respiration?
442. Frequency of this operation and amount of air.
443. The changes upon the air, experiments.

754. The following rough estimate will give some idea of the large quantity of carbon consumed by man alone; to avoid fractions, approximative numbers have been taken in estimating the population of different places.

	Population.	Tons of carbon consumed daily.	Tons of carbonic acid produced daily.
Edinburgh	150,000	22	80
London	1,500,000	220	800
Whole globe	800,000,000	117,333	426,666

755. The annual consumption of carbon, accordingly, by man alone, may be estimated at 42,826,566 tons, and the annual production of carbonic acid at 155,733,333 tons.

756. During the respiration of vegetables, at least in the sunshine, carbonic acid is decomposed, carbon retained, and oxygen evolved.

757. Hence, then, the two great systems of animated nature, each counteracting the influence of the other by those processes which are essential for their nourishment and support, are believed to maintain the air in that state of equilibrium which is so necessary for the existence of both.

CHAPTER XXXII.

FLAT GLASS, TUBE, AND BLOWPIPE APPARATUS.

758. When slips of glaziers' window-glass are properly selected, they may be used for the following purposes:—

759. I. *Solution.*—Broad slips of the size seen in figs. 85 and 86, or twice the length and breadth seen there, are best adapted for this purpose; they are held by one ex-

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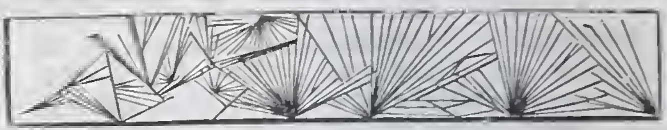
444. Proportion of carbon evolved and consumed.
445. Difference between animals and plants.

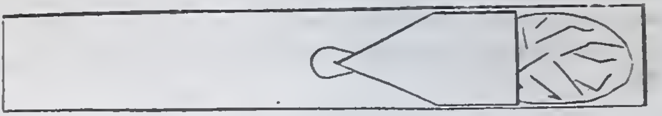
tremity, and a minute quantity of the substance to be dissolved, about the size of a mustard seed, is placed at the other, covering it with eight or ten drops of the liquid used for solution.

Fig. 85.



760. II. *Boiling liquids.*—Slips of the same size as fig. 85 may be employed, but they ought to be selected as thin as possible; those which are about the 20th of an inch in thickness do well. The part heated should be covered for the length of an inch or two with the liquid to be evaporated; the slip may be placed before the fire, in a current of warm air, or one or two inches above the flame of a very small lamp or candle.

Fig 86.



761. III. *Crystallization.*—Solutions to be crystallized may be spread over the greater part of the glass, and left to evaporate spontaneously, or concentrated by heating, removing the slip from the heat the moment any solid appears on the edges; if the heat be continued longer, a confused mass is generally observed instead of crystals: fig. 85 represents the appearance frequently seen, where small needle-like crystals are produced. Glauber salts (sulphate of soda), oxalic acid, hydrochlorate of strontia, and bichloride of mercury, give solutions which crystallize with great facility.

762. IV. *Filtration.*—When a solution is turbid, from the admixture of solid matter, it should be collected at one extremity: a small tapered piece of bibulous or filtering paper is then placed next it, as in fig. 86, when the fluid

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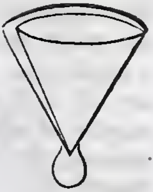
446. Describe simple apparatus for solution, &c.

in general passes along, and a drop of clear fluid is obtained at the pointed extremity of the paper. The glass slip should be gently inclined, and more water or other solvent should be added, if there be not enough to moisten the paper. When the solution does not filter readily in this manner, a square piece of paper may be folded in two, this being again repeated, so that on opening it in the manner seen in fig. 87, the fluid may be poured into it as it rests on the side of the flat glass.

Fig. 87.



763. V. *Distillation.*—In a few cases, if a very cold slip of glass be held above a fluid evaporating steadily on another slip, part of the vapour may be condensed and retained on the cold slip.

764. These slips, or the narrow slip represented in the following figure, may also be used for *precipitation.*

765. VI. *Slips* for *testing. stirring,* and *lifting fluids.*—These are made of the form and size shown in fig. 88. Dipped into any solution, a portion adheres to the extremity; it may then be divided into many small portions, upon a broad slip of glass or paper, by touching it with the end of the slip to which the fluid adheres. The narrow slips being cleaned in a basin of water, may then be dipped into any tests, and applied to each separate portion distributed over the glass or paper, as in fig. 89.

Fig. 88.

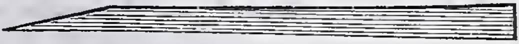
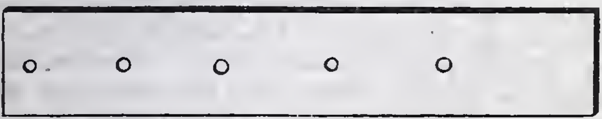


Fig. 89.



766. VII. For *fusion* and *decomposition*, the broad slips may be employed where an intense heat is not re-

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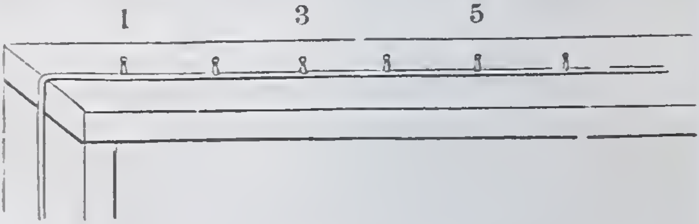
447. Instruments for crystallization, filtration, &c.
448. Describe articles used in experimenting.

quired. In examining the effect of heat where a more elevated temperature is necessary, the narrow slip should be employed, and no more taken up than can be lifted by the point, the quantity not exceeding in bulk the head of a small pin. Practise experiments of this kind with acetate of lead, red lead, sulphate of copper, sulphate of iron, nitrate of silver, terchloride of gold, and any other substances, the effect of heat upon which has already been described.

767. In experimenting with borax and metallic oxides or other substances, heat the pointed extremity for half a minute, dip it instantly into powdered borax, a portion of which immediately adheres; it is then brought in contact with the substance to be fused along with it, moistening it, if this be necessary, to make a little adhere. The material is usually heated in the flame of a lamp or candle; in the outer flame, *a*, *a*, fig. 41, hot air acts upon it, but in the inner flame, it is subjected to the action of hot carbon and hydrogen. Between these is the point of greatest heat.

Fig. 90.



768. Fig. 90 shows the arrangement adopted in placing the gas or other lamps, at Heriot's Hospital, in the Scottish Institution, in the School of Arts, and other places, where from 40 to 120 pupils operated at once. The benches are arranged so that the teacher is in the centre, and able to command a view of them all. Cups, glasses, or saucers, with the materials, are placed at one end of each, and a basin of water at the other.

BLOWPIPE.

Fig. 91.

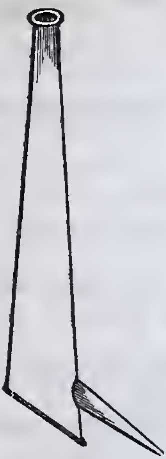
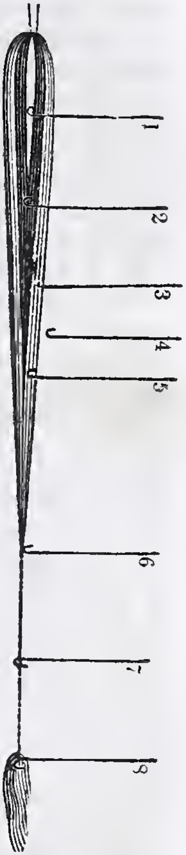


Fig. 92.



769. Fig. 91 represents a blowpipe made of tin, with a brass nozzle inserted at the lower extremity. The upper part of the tube, into which air is blown by the mouth, is 3-10ths of an inch in diameter, the lower part an inch, and the nozzle, which proceeds from it, and is inserted into the flame of a candle, or of an oil, tallow, or gas lamp, terminates in an opening about 1-40th of an inch in diameter. By blowing through this tube, when the nozzle is held in any flame, it may be made to produce a conical flame, or *blowpipe dart*, as it is frequently termed, with which numerous experiments may be performed, where small portions of matter are subjected to its influence. The outer part of the flame abounds in oxygen derived from the air, and is termed the *oxidating flame*; the inner part, when yellow, and loaded with hydrogen and carbon, is termed the *deoxidating flame.* The carbon and hydrogen tend to remove oxygen. The blowpipe may be made ten inches long. Fig. 92 illustrates the more important points to which the student should attend at first, in examining minutely the nature of the blowpipe flame. He will proceed most satisfactorily by heating a small platinum wire, such as is shown in the figure, in the various places represented at the different positions in which it is placed.

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449. What is said of the blowpipe, and its use?

1. Points out an interior oxidating cone, so small that it is scarcely noticed under ordinary circumstances, and formed by air proceeding directly from the blowpipe.

2. The blue flame, which becomes highly deoxidating when it passes into a very luminous and carbonaceous flame.

3. Shows the outer flame, which consists principally of products of combustion.

4. Hot air beyond the outer flame, which is highly oxidating.

5. The point of greatest heat.

6. The termination of the visible flame.

7. Hot products of combustion, oxidating or not, according to the air mixed with them.

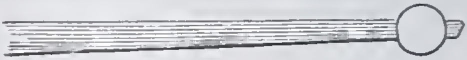
8. A point at a certain distance from the visible flame, at and beyond which an oxidating effect is always to be observed.

If a salt containing soda be made to adhere to the platinum wire, it presents the appearance seen at 8.

770. By blowing with the cheeks distended like a trumpeter's, and endeavouring to renew the blast as speedily as possible when it intermits during inspiration, the habit of keeping up a continued blast is acquired, the air with which the cavity of the mouth is filled being used to maintain the stream, while a fresh portion passes down by the nostrils to the lungs.

771. When a metal is to be procured from an oxide, or any deoxidating effect to be produced, a charcoal support is used; a piece of wood heated at one end in the fire so as to become black does very well. Red oxide of lead, and aqueous sulphate of copper, are much used in practising the extraction of metals by the blowpipe. If the outer flame is to be used, a slip of glass, with a small earthen cup at one extremity (fig. 93) is the most convenient support; if the extremity be touched with a minute quantity of a solution of silicated potassa, it adheres firmly,

Fig. 93.



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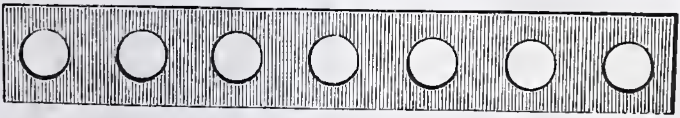
450. Explain the use of these instruments.

and any substance placed upon it may be exposed with facility to the action of the outer flame, and all the effects produced and seen with great distinctness.

772. These *blowpipe cups* are prepared in the following manner. Procure a piece of brass, one-twentieth of an inch thick, of the size shown in fig. 94, and with seven round holes in it. Place it upon a slip of paper, and fill up the apertures with pipe-clay, previously mixed with water, and having the consistency of dough. Remove any superfluous clay with the finger; then press them with the finger, the brass mould and paper resting on the left hand, so as to give them a cupped form. Dry them slowly before the fire for an hour or two, and heat them to redness in a crucible to make them fit for use.

Fig. 94.



773. Heat iron, lead, copper, zinc, tin, bismuth, and antimony, on these cups, in the outer flame, and compare the effect produced with what is observed when they are heated on charcoal.

774. Fuse a little borax on several cups, using it alone on one, and touching the others with a little of each of the following substances:—Binoxide of copper gives a green glass; metallic copper is seen in the inner flame. Binoxide of manganese produces an amethystine tint. Arsenuret of cobalt (common ore of cobalt), mixed with an equal weight of nitre, produces a fine blue. Try also the borax on the cups, after touching it with a solution of gold. A ruby-coloured compound is formed.

775. Fig. 95 shows another form of the common blowpipe, fixed to a small plate of lead, so that its motion can be regulated by the mouth, and the hands left free for experimenting. A form of gas-burner is represented there, which is much employed in blowpipe experiments. The

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451. Define the several articles of apparatus.

jet represented in fig. 49 is also well adapted for this purpose.

Fig. 95.

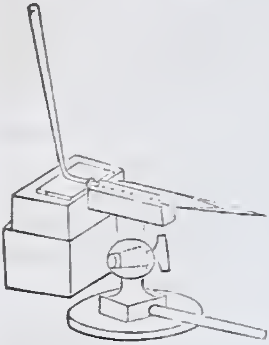


Fig. 96.

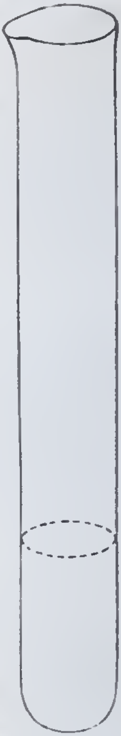


Fig. 99.

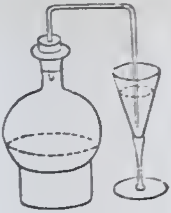


Fig. 98.

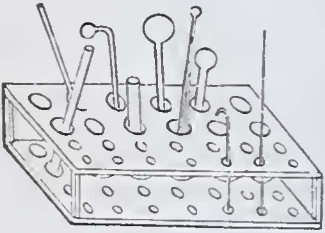
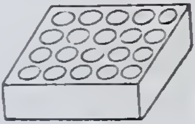


Fig. 97.



TUBE APPARATUS.

776. *Tubes of thin glass*, of the size and form shown in fig. 96, are extremely convenient for numerous experiments where gases are evolved, liquids to be boiled, or solids to be heated and sublimed. Cases for holding them may be easily made of wood, of the form represented in figs. 97 and 98. Small retorts and receivers, pipettes and funnels, are frequently made with tubes, for operating on minute quantities of different substances.

CHAPTER XXXIII.

MISCELLANEOUS APPARATUS—MATERIALS FOR EXPERIMENTS.

777. Flasks of the form shown in figs. 100 and 101 are much used in a variety of experiments. Fig. 102 represents two small flasks, or bulbs of glass, connected by an intermediate tube, so as to be used as a small retort and receiver. The wide flask, fig. 100, if four or five inches in diameter, does well for burning phosphorus and other materials in oxygen; these are supported on a stand, as in fig. 35, the support being of a height equal to the length of the neck of the flask; the flask, full of oxygen gas, is then placed over the inflamed material; the mouth being downwards, and allowed to rest on rather a rough or grooved surface, that part of the oxygen may escape freely as the expansion proceeds.

Fig. 100.

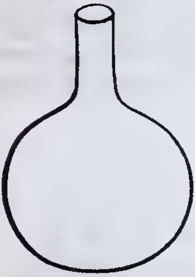
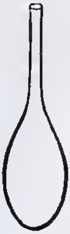


Fig. 101.



Fig, 102.

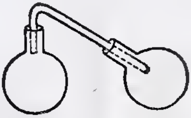
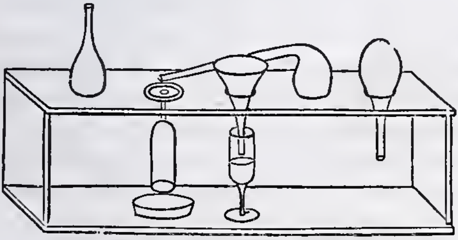


Fig. 103.



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452. Cite the experiments named.

778. Fig. 103 shows the form of a wooden stand with a number of apertures, very convenient for giving a temporary support to retorts, flasks, funnels, and other apparatus.

779. Fig. 104 is intended to give an outline of a very plain form of a retort stand, which is extremely useful, and may be made in a very short time by any blacksmith. It consists of a small plate of wrought-iron, seven inches long, three broad, and one half of an inch thick. A stem rises three-eighths of an inch in diameter, and ten inches long. Rings are made of iron-wire, which are supported by coiling the wire two times and a half round the stem. These may be moved readily upon the stem, but when any weight rests upon the extremity, they become quite fixed.

Fig. 104.

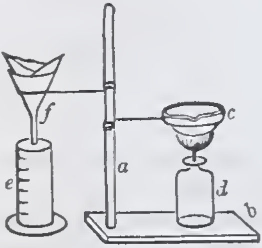


Fig. 105.

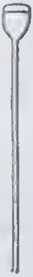
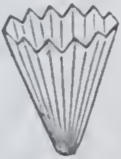


Fig. 106.

Fig. 107.



780. Figs. 105 and 106 show the form of the long funnel for introducing liquids into a plain retort, and of a common funnel, such as is used for filtration. Fig. 107 represents a piece of filtering paper, folded in the manner required where liquids must be filtered quickly.

781. Figs. 108, 109—a rake and scraper required in furnace experiments. Figs. 110, 111, show the form of small wires of platinum, used for supporting minute quantities of materials in the flame of a lamp.

782. Figs. 112, 113, 114, represent different forms of tongs and pincers. Fig. 115—a crucible and its cover.

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453. The names and uses of the apparatus.
454. Names and uses of the instruments.

Fig. 108.

Fig. 109.

Fig. 110.

Fig. 111.

Fig. 112.

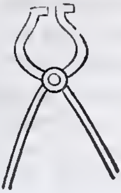


Fig. 113.

Fig. 114.

Fig. 116—a crucible covered with another luted to it, gas being carried off at an aperture made in the top. **Fig. 117**—tin pincers.

Fig. 115.

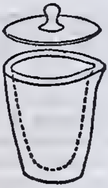


Fig. 116.

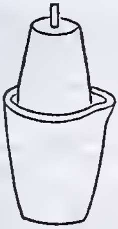
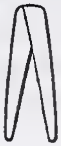


Fig. 117



783. A conical piece of tinned iron, open above and below, being filled with clay, and a piece of hard wood of the same form, but a little smaller, being pressed into it, a crucible is at once obtained, which must be dried and heated slowly before it is used. The tin and the wood must be well oiled to enable the crucible to be removed. Small crucibles, two inches deep, one inch and a half wide at the top, and tapering a little to the bottom, are very convenient for numerous experiments.

784. In using retorts, flasks, and crucibles, they should not in general be filled more than one-third full, where the materials are apt to effervesce or boil over.

785. Pneumatic jars (see par. 243, fig. 24) must be filled cautiously with water when they are mounted on the

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455. What precautions are needed?
456. Care necessary in experiments.

shelf *b*, to prevent them from being knocked over by any sudden movement in the fluid ; the spout *c* leads any excess of water into the box *f*.

786. Small pieces of tin, copper, iron, and zinc wire, plate or foil, are very useful in experiments on the small scale.

787. *Solutions* are usually prepared by merely agitating the solid with water, or some other solvent, if it be very soluble : the mixture is boiled, if the substance be sparingly soluble.

788. *Equal weights* are always understood when the term " parts" is used, unless parts by measure be specifically mentioned.

789. Cubic inches are expressed by c. i., weight by W., volume by V.

790. The following table may be frequently referred to, so as to enable the experimenter to calculate the weight of materials used from the amount of the measure.

	Specific Gravity.	Weight in Grains of		
		1 Ounce.	1 Drachm.	1 Minim.
Distilled Water . .	1·000	455·72	56·96	0·947
Sulphuric Ether . .	0·720	328·12	41·01	0·683
Alcohol	0·796	362·76	45·34	0·749
Solution of Ammonia	0·925	421·54	52·69	0·878
Hydrochloric Acid .	1·118	509·50	63·68	1·061
Nitric Acid . . .	1·480	674·47	84·30	1·405
Sulphuric Acid . . .	1·848	842·18	105·27	1·754

Memoranda.

60 drops or minims = 1 drachm.
8 drachms - = 1 ounce.
16 ounces - - = 1 pint.
8 pints - - - = 1 gallon.
Imperial pint - = 8750· grs. of distilled water.
Imperial fluid ounce = 437·5 ....
Cubic inch - - = 252·458 ....
Pound, avoirdupois = 7000· ....
Ounce, avoirdupois = 437·5 ....

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457. What is said of weight ?
458. Repeat the table.

791. The small museums, with flat glass, prepared by chemists, consisting of about sixty specimens, with bottles containing the most important acids and alkalies, are extremely useful in enabling the student, who has neither time nor opportunity to operate with more extensive apparatus, to make himself familiar with a wide range of chemical phenomena.

792. The following list of materials and apparatus may be useful to those proposing to commence a series of experiments by themselves.

[An asterisk (*) indicates that the substance before which it is placed should be kept in solution as well as in the solid form. Phials capable of holding from one drachm to two or three ounces, will do extremely well for this purpose. Boxes containing the materials, &c. represented below, should not cost more than about £3: when of the larger size, and intended for introductory courses in schools and academies, from £5 to £10 may be expended upon them.]

Sulphuric, Nitric, and Hydrochloric Acids; Solutions of Potassa and Ammonia—must all be kept in stoppled phials.

Sulphur.
Phosphorus.
Iodine.
*Fused Potassa.
*Carbonate of Potassa.
Bicarbonate of Potassa.
Sulphate of Potassa.
Nitrate of Potassa.
Chlorate of Potassa.
Bitartrate of Potassa.
*Ferrocyanate of Potassa.
*Bichromate of Potassa.
*Iodide of Potassa.
*Silicated Potassa.
*Carbonate of Soda.
Bicarbonate of Soda.
Phosphate of Soda.
*Oxalate of Ammonia.
*Carbonate of Ammonia.
*Hydrosulphuret of Ammonia.
*Chloride of Lime.
*Hydrochlorate of Lime.
Sulphate of Lime.
Phosphate of Lime.
Phosphuret of Calcium.
Fluoride of Calcium.
Sulphate of Baryta.
*Nitrate of Baryta.
Sulphuret of Barium.
Strontia.
*Hydrochlorate of Strontia.
Magnesia.
Sulphate of Magnesia.
*Alum.
Silica.
Iron.
Oxide of Iron.
Peroxide of Iron.
*Sulphate of Iron.
*Perhydrochlorate of Iron.
Lead.
Sulphuret of Lead.
Litharge.
Red Oxide of Lead.
Carbonate of Lead.
*Acetate of Lead.
*Nitrate of Lead.
Ore of Cobalt (Arsenuret).

Tin.
Bismuth.
Antimony.
Sulphuret of Antimony.
Copper.
•Sulphate of Copper.
•Nitrate of Copper.
Zinc.
Oxide of Zinc.
Arsenious Acid.
Sulphuret of Arsenic.
Binoxide of Manganese.
Mercury.
Binoxide of Mercury.
•Bichloride of Mercury.
Bisulphuret of Mercury.
Bicyanide of Mercury.
•Nitrate of Silver.
•Bichloride of Platinum.
•Terchloride of Gold.
•Tincture of Galls.

•Oxalic, Tartaric, and Benzoic Acids.
Cabbage, Turmeric, and Litmus Test-Papers; Filtering Paper
Chalk or Marble, Sulphuret of Iron, and Borax, may be provided in larger quantity.

Pneumatic Trough with Shelf.
Pneumatic and Precipitate Jars, with Tin Trays.
Tube Retort, Receiver, and Funnel.
Basin for Evaporating.
Watch Glasses.
Test-Tubes.
Pipettes.
Bottle and Bent Tube.
Spirit-Lamp.
Glass Funnel.
Slips of Glass for Solution, Evaporation, Crystallization, Fusion, and Testing.
Apparatus for Instantaneous Light.
Retort, Stand, and Ring.
Cupped Iron Block with Iron Bar.
Triangular Supports made of Wires of different Metals.
Crucibles.
Blowpipe.
Blowpipe-Lamp.
Blowpipe-Cups.
Brass Mould for making them.
Platinum Wire.
Supports for Candles, Sulphur, Phosphorus, Test-Tubes.
Iron-Wire, Slips of Copper and Tin.
Phials, Test-Tubes.

793. Paper dipped in different fluids is well adapted for illustrating a great variety of chemical phenomena. Dip different slips of paper into solutions of nitre, nitrate of lead, and nitrate of copper; dry them and set them on fire, so as to burn without flame; carbonate of potassa, highly alkaline, is produced with the first, metallic lead and copper with the others—the copper immediately attracting oxygen, and assuming a dull appearance.

ELEMENTS

OF

CHEMISTRY.

PART II.

ELECTRICITY.

BY

ALEXANDER BAIN.

CHAMBERS' EDUCATIONAL COURSE.

PREFACE.

ELECTRICITY is the branch of Natural Philosophy most closely allied to Chemistry. Hence, although in the order of study Chemistry comes after Natural Philosophy, a certain acquaintance with the primary facts of Chemistry will be of use in facilitating the comprehension of some portions of the present subject, particularly Voltaic Electricity. Before entering upon that department, the teacher will find it advantageous to state, and illustrate by a few familiar examples, the nature of chemical combination and decomposition, and to distinguish these from mixtures and separations that are not chemical. The leading properties of chemical union are the fixed proportions of the combining substances, the giving out of heat, (as in burning,) and the total difference between the resulting compound and either of the individuals in their whole aspect and properties. Thus a certain weight of sulphur, combining with a fixed proportion of copper filings, will produce heat while the union is going on, and will turn into a black substance where neither copper nor sulphur could be recognised, and which could not serve any one of the special purposes of either.

In this, as in the preceding Treatises, great pains have been taken to render the arrangement as perspicuous, and the language as simple and intelligent, as the subject would allow.

ALEX. BAIN.

November, 1848.

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PART II.

ELECTRICITY.

OF POLAR FORCES IN GENERAL.

1. THE force of gravity is always of one kind, and is the same on all sides of a gravitating mass. The earth, as a heavy body, attracts all other heavy bodies, whatever be their shape or position. Constant and unremitted attraction is the peculiarity of this force. In like manner, the ordinary appearances of cohesion and capillary attraction are uniform under all arrangements of the particles or surfaces in contact. One drop of water is seen to attract another drop, a plate of glass attracts a liquid surface, both after an unvarying fashion. In the adhesion of the particles of a liquid among themselves, it is evident that each particle attracts the particle next it, whatever side it may present; for although we stir the mass about, so as to make the particles turn round among each other, they still show a mutual attraction. The whole surface round and round of an atom of water has an evenly-spread attractive power towards the whole surface of every other atom; whatever points are brought together, the degree of attraction will be equal, just as the earth will draw a body downwards with the same force on any side. In like manner the *repulsion* caused in bodies by heat, as in air, (whose particles all tend to fly off from each other,) is a constant repulsion. No movement among the atoms, as by stirring them and changing their places among each other, alters their

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1. How does gravity operate on the mass attracted? What is the peculiarity of this force? What law is shown of the particles of liquids and solids? Show a similar law in the action of heat on air.

repulsive tendency. It is manifest in this case also, that each atom of air is actuated evenly all round its body with a repelling power towards every other atom. If we supposed any one atom turned half round or quarter round in its place, it would oppose different points to the atoms next it, but the new points would repel in exactly the same manner as the old.

2. But nature makes use of forces that have not the unvarying character either of gravity, liquid cohesion, or gaseous repulsion. We find a kind of force inhering in atoms and masses of matter that is repulsive at one side of each atom or mass, and attractive at the opposite side. If we have two bodies adhering to one another by this force, and if we take one of them and turn it about so as to place the opposite end next the other, there will be no attraction; on the contrary, there will be a repulsion, and this repulsion will probably have the same strength that the previous attraction had. In this case, therefore, the mutual position of the bodies is an essential circumstance. Each mass has its power gathered into its ends, but the ends have contrary actions. If the forces on two opposite points were joined together, they would neutralise each other, and cause perfect indifference on the whole. To forces of this character the name POLAR is given; and bodies actuated by them are called polar, or polarised, or are said to have the attribute of polarity.

3. When bodies are crystallised, the force by which their atoms adhere is a polar force. An atom of ice will not adhere to another atom on any side; a certain point of the one clings to a certain point of the other; and if one of a pair of adjoining atoms were to have its ends reversed, the two atoms would repel one another violently. Hence crystallised bodies cannot have their particles stirred about like a liquid, or like red-hot iron; the least disturbance causes a fracture. If a particle is moved from its proper position, it either ceases to attract or it becomes repulsive, and there

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2. Describe the force mentioned, different from gravity. Where, in bodies, does this force reside? Give its name. 3. Show how it operates in ice. When is adhesion general? How is polar attraction destroyed?

is an end to the cohesion. The property of *brittleness* generally indicates a polar cohesion. Malleability and ductility, or mobility of parts, show that the cohesion is not polar, but general, and evenly distributed over the entire surface of the particles. When bodies are at their highest pitch of solidity, hardness, or compactness of structure, they have generally the polar cohesion. This cohesion is uniformly destroyed by heat, which softens, melts, and finally evaporates solid substances. And in many other cases besides crystalline cohesion, heat is the destroyer of polarity.

4. Throughout the whole range of actions that are included under ELECTRICITY, polarity is an invariable characteristic. It is not possible to produce an electrical attraction without an equal repulsive power conjoined. Every electrified body is attractive at one end and repulsive at the other, or is polarised, like an atom of a crystal. It is in electricity that we can most completely study the nature and laws of polar force, for there we have it under the greatest variety of different circumstances and modes. It is not confined to electricity; we see it also in light. Chemical forces have certainly a polar nature, and some of the vital forces appear to have the same character. Whether all the polar forces arise from one identical agency or from many, they at least serve to illustrate and explain each other; and the electrical phenomena present the most visible and tangible instances of the polar mode of action.

5. The word "electricity," taken from the Greek name for *amber*, (which strongly exhibits the phenomena when rubbed,) was at first applied to the electrifying of bodies by rubbing or friction; but it is now the general name for seven different kinds of electrical excitement. These seven kinds fall under two heads. When the excitement is in a state of repose, and maintains itself, it is called STATICAL ELECTRICITY; when the excitement is in a constant current, and requires to be continually renewed, it is called CURRENT ELECTRICITY. The subdivisions of each are as follow:—

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4. What is necessary to produce an electrical attraction? What is true of every electrified body? Where are polar forces found? 5. Mention the classes of electricity. Their characteristics. The divisions of each class.

STATICAL ELECTRICITY.

1. Magnetism.
2. Frictional or Tension Electricity.

CURRENT ELECTRICITY.

3. Voltaic Electricity.
4. Electro-Magnetism.
5. Magneto-Electricity.
6. Thermo-Electricity.
7. Animal Electricity.

MAGNETISM.

6. There is a certain ore of iron (an oxide, or a combination of the metal with oxygen) that has the property of attracting pieces of iron, and of communicating its attractive power to bars of steel. This ore is called the *loadstone.* The name *magnet*, also applied to it and to the bars of steel that have acquired its properties, is supposed to be derived from Magnesia, a country in Asa Minor, where it was first discovered.

LAWS OF MAGNETIC PHENOMENA.

7. The first principle of the magnetic force may be stated thus: *The magnet has always two poles or points where the power seems concentrated.* If we dip a magnetic bar into iron filings, on lifting it up we find a considerable quantity of the filings adhering to it, in consequence of its attraction for iron. On observing it closely, we see that the greatest mass of filings is attached to the two ends, that there is a gradual decrease towards the middle, and that in the middle point itself there is none. Hence it is said that the poles, or centres of the force, lie in the ends of the bar. A heavier piece of iron will be suspended at one of the ends than in any other place. The actual poles or points of highest concentration in the case of a

---

6. What is oxide of iron? What is loadstone? To what is the term magnet applied? Where was loadstone first found? 7. What principle is stated of the magnet? Give an illustration of this.

bar, are each in the interior of the bar at a small distance, probably from a quarter of an inch to an inch from the extremities. Whatever be the shape of the magnetic mass, two such centres will be found in it. If a loadstone, or a steel magnet, is broken in two, each fragment will have two poles the same as the entire body; and this would hold if it were broken into any number of pieces. The poles are not of themselves the sources of the power. They resemble rather the centre of gravity of a body; which is the point, not where the gravity is actually lodged, but where, if it were lodged, the action of the body would continue the same; and which is continually changing with the changes of shape or contents that the body undergoes. The magnetic poles represent the total magnetism of the mass; when we speak of a body's distance from the magnet, we measure this distance from a pole. As a gravitating mass is a collection of gravitating atoms, so a magnet is a collection of magnetic atoms, each with its two poles; and when the forces of all the atoms are joined together, the result is the same as if the magnet were only a pair of atoms, placed asunder at the distance of the two poles, and possessing opposite attractions.

8. *Magnets repel each other by their like poles, and attract each other by their unlike poles.* The two poles of a magnet, as of all polarized bodies, have opposite actions; what the one will attract, the other will repel, and what the one will repel the other will attract. If we have two different magnets, and if we take a third magnet to try their action upon, we shall find out which is the like, and which the unlike poles. Present one end of the first to one end of the third; and suppose we find that they attract each other. Present next one end of the second to the same end of the third; if an attraction now takes place, the poles of the first and second that have thus shown a common attraction for one pole of the third, are *like* poles; they have both precisely the same action

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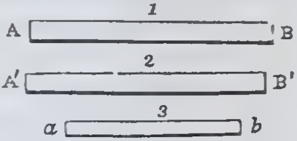
Where are the poles of a magnetic bar? If the bar is broken, what results are noted? What do the poles represent? 8. How do magnets attract and repel? How can we discover the like and unlike poles?

on one object. Their other ends, if tried in the same way, would show an identical action on the common object, and would also be like poles. But if a pole of the first attracted, and a pole of the second repelled, the same pole of the third, the poles of the first and second thus tried would be unlike poles Thus, in the figure, suppose that the pole A of No. 1 attracted the end *b* of No. 3, and the pole A′ of No. 2 also attracted *b*, A and A′ are like poles; but if, while A attracted *b*, A′ repelled it, A and A′ would be unlike poles. Now, from the nature of polarity, the two poles of the same magnet are always unlike; that is, if A attracted *b*, B would repel *b*. By reversing the acting magnet while the magnet acted on remains, we get an opposite action.

FIG 1.



9. Supposing, therefore, it is found by such a trial that A and A′ are the like poles of the two magnets. Let us bring these two poles together, and the action is repulsion. So, if we bring the other ends together, B and B′, which also are like poles, they will repel each other. But if we bring A and B′ together, which are the unlike poles of the two magnets, they will attract each other, and adhere with more or less force according to their strength. The same will happen if we bring A′ and B together. And if, in the trial of the two first upon the third, it appeared that A and A′ attracted *b*, this would be a proof that the pole *b* was unlike the poles A and A′, and like their opposites B and B′; and that *a* is the pole like to A and A′.

10. The two poles of a magnet are distinguished by the names North and South, from the north and south poles of the earth. The end of a magnetised needle or bar that points to the north pole of the earth when suspended freely, was at an early period termed the north pole, and the opposite end the south pole. This usage still continues, although erroneous. In fact, the end that is attracted to

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Explain the figure. How are the two poles of a magnet? 9. How do like poles act upon each other? Unlike poles? 10. What names have the two poles of a magnet? Are these names accurate?

the north is, for that very reason, *unlike* the north magnetic pole of the earth, and ought to have been termed the south pole of the magnet.

11. It thus appears that there exists within each magnet two contrary influences, which repel each other, and, through this repulsion, are distributed into the two farthest ends of the mass. Half-way between the poles is the cross line of neutrality. It is the place where the two opposing forces balance one another, and prevent an attraction taking place either way. We must regard the force even at one of the poles as a difference of two forces; for when a needle is attracted to the north pole of the magnet, it is under the repulsion of the south pole at the same instant. It is kept to the north pole only because it is nearest; for the magnetic force diminishes by distance. It is from the neutral line being equally distant from both poles that its neutrality arises. An object placed there is like the matter in the earth's centre, which, being equally attracted on all sides, shows no tendency to any.

12. *The attraction of magnets for unmagnetised iron arises from a temporary communication of magnetism, called induction.* If we bring a few iron filings or pieces of soft iron near the pole of the magnet, they will be attracted; if we take them off, and apply them to the other end, they will still be attracted. This at first sight appears to contradict the general statement as to the contrary nature of the two poles. But on nearer examination, it becomes perfectly consistent; and a new property of magnetism is disclosed by it. When we bring one end of a piece of soft iron near the pole of the magnet, the soft iron is itself rendered magnetic. Each magnet is, as it were, surrounded with an atmosphere that communicates the power to all iron masses that approach it. This temporary magnetism is always arranged in opposition to the forces of the principal magnet. The end of the soft bar touching the north pole of the magnet becomes a south

---

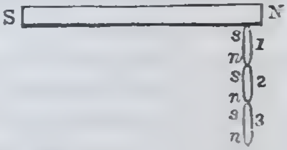
11. Where, in a magnet, is there no attraction? Why none at this point? 12. By what means do magnets attract iron? What is this called? What takes place in iron that is attracted?

pole; and the other end is a north pole, as may be seen by bringing the south pole of another magnet near it. While in actual contact with the magnet, the iron is not indifferent; if we try the remote end by a pole like the one that attracts the near end, we will see an active repulsion: so that a magnet attracts iron because it has the power of making it a magnet for the time The iron in contact is rendered polar throughout, and has this polarity concentrated in two opposite poles exactly like the loadstone. A magnet cannot attract silver, because it has not the power of imparting the magnetic state to atoms or masses of silver. Iron seems by nature susceptible of magnetism, and when once it is magnetised, it can attract other iron by magnetising it in turn.

13. The existence of this temporary influence, called *magnetic induction*, proves that polar bodies attract none but polar bodies. When a neutral body is brought near a polar body, there will be no action unless the neutral body is first polarised by the neighborhood of the other.

14. When a magnet suspends iron filings, they may be seen hanging from it in threads, clinging, not all to the magnet, but to one another in a chain. This action is best understood by taking a few iron balls, or little bits of wire, and suspending one of them to a pole of the magnet. By this suspension it is made a magnet for the time, and two active poles are developed in it. If the north pole of the magnet is used, the wire 1 will have its upper end a south pole, and its lower end a north pole, ready to attract iron, as if it were a permanent loadstone. Bring now the wire 2 into contact with the first. The active north pole of No. 1 will develop an active south pole in the upper end of No. 2, and an active north pole at its lower end; the unlike poles will attract each other, and the second will hang by the first, and will

FIG. 2.



Has the attracted iron poles? How is this shown? 13 What does induction prove? 14. If a wire is suspended to a magnet, which of its poles touches the magnet? Explain the operation in another wire suspended to the first.

have the power of communicating the same polarity, and exercising the same attraction for a third wire. The weight of wires that can be polarised and suspended is limited by the power of the magnet. As the lower end of the above series is a north pole, it may be carried across to the other end of the magnet which is south, and there attracted; and we will thus have a chain hanging from end to end of the magnet, each joining presenting a pair of opposite poles. The inductive strength of the two ends being combined in this case, a greater weight will be sustained than could be borne by a single pole

15. We must conceive the atoms composing the magnet itself as exercising the same inductive power on one another, and in this way combining their strength together. But for this power which each little magnet has to throw its strength, as it were, into an adjoining magnet, there could be no accumulation of force. A chain never can be stronger than its weakest link; and the end of a line of magnetic atoms would have no greater strength than a single atom, unless each atom was heightened by the inductive force of the whole series. No. 1 has of itself a certain degree of polarity; No. 2 has in like manner a certain independent strength; when the two go together, the first adds its inductive strength to the natural polarity of the second, and the second does the same to the first, and each is now so much stronger than before. It is like the lowest stratum of a fluid which presses not only with its own gravity, but also with the accumulated gravity of all that lie above it.

16. *The power of the original magnet is exalted by the induction.* By connecting the two ends of a magnet by a rod of unmagnetised iron, the latter becomes magnetic under the induction, and seems to react upon the magnet by its induction, so as to maintain, and even to increase, its polarity. Left to itself, with its poles unconnected, a magnet's power gradually decays. The series of inductive

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May the chain be joined to the opposite end of the magnet? Why?
15. Do the atoms of a magnet act on each other? Explain this action.
16. How is the power of a magnet affected by induction? Illustrate this.

polarities must form a circle to acquire the highest degree of intensity; and when an unmagnetic bar joins the poles, the exercise of the induction upon the fresh matter gradually heightens the sum of the polarity.

MAGNETS.

17. *The loadstone* has been termed the natural magnet, because it seems to have magnetism permanently engrained in its constitution. It is found in all parts of the world, and sometimes forms rocks of considerable size. Its strength is very unequal in different specimens. As a general rule, a small loadstone will carry a greater weight in proportion to its size, than a large one. It has a grayish color, and a dark metallic lustre. Although an oxide of iron, it is not identical either with rust, or with the scales of iron formed by burning iron wire in oxygen gas.

18. Artificial magnets are formed from bars of well-tempered steel. The instantaneous influence of a magnet on a steel bar is not so great as on soft iron, but the steel retains the polarity that has once been communicated to it. To magnetise the steel thoroughly, motion and friction are used. In general, if we take a loadstone, or a bar already magnetised, and rub one end along a steel bar repeatedly, and always in one direction, the steel bar will become magnetic; but in order to make the process effective, a mode of action must be used that uniformly tends to give one kind of magnetism to the bar; that is, that always developes the same pole at the same end. If one part of the stroke tends to give a south pole, and another a north, to one end of the bar, the contradiction will destroy the effect. In rubbing a bar with a magnet, we ought to commence at the middle of the bar, and rub from thence to one end with one of the poles of the magnet; the magnet should then be reversed, and placed at the middle as before, and rubbed towards the other end of the bar. And the process should be repeated in the same order; one end of the

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17. Describe the loadstone. 18. How may artificial magnets be made? If the same pole be rubbed on the two ends of the bar, what will be the effect? How should the loadstone be rubbed on the steel?

magnet always going out to one end of the bar, and the other end of the magnet to the other end of the bar alternately. The bar will then be magnetised in such a manner that each end will be opposite to the end of the magnet that rubbed it. The same inductive action that renders soft iron temporarily magnetic by mere contact, comes into play here; but steel offers more resistance to the action than iron, and the friction is needed to overcome the resistance. The magnetic state thus forcibly communicated remains permanently in the steel bar, which has henceforth the character of the natural loadstone.

19. In practice, it is found best to use two magnets to rub with, and thereby to perform both the rubbings at once. Opposite ends of the two rubbing magnets are laid together on the middle of the bar to be magnetised, and they are held so as to make a small angle with the bar; they are then drawn along, one to one end, and the other to the other end, repeatedly. The bar itself is laid in a straight line with two other magnets, which exert upon it the inductive contact while it undergoes the friction of the rubbing magnets. This method is found very suitable in magnetising needles for compasses. Another method, called the *double touch*, consists in arranging the bar as before, with magnets in a line with each end, and using two rubbing magnets with opposite poles brought together; but instead of beginning at the middle of the bar, and separating the two, and drawing them apart to the two ends, they are held together and rubbed from end to end backwards and forwards. The inclination in this case is to be still smaller than before. The ends of the rubbing magnets are not in actual contact, but press upon a wedge of wood or brass which lies between them. This method communicates a very intense degree of magnetism; but is apt to make the poles of the bar unequal in strength.

20. Instead of being a straight bar, it is convenient to give magnets the form of a horse-shoe, which brings their

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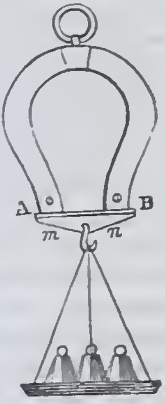
What difference is there in the facility of magnetising iron and steel? 19. What is the best method of magnetising a bar? For what is this method suitable? Describe the method called the double touch.

poles near each other, and makes it easy to complete the circle, and to bring both poles into play upon the same object. Such a magnet is represented in the following figure. A and B are the two poles; they are joined by the bar *mn*, which is of course polarised; *m* having the opposite magnetism from A, and *n* from B. Each horse-shoe magnet is permanently furnished with such a cross-piece, made of soft iron, which is called the *keeper*, and sometimes the *lifter*, and also the *armature.* When the magnet is used to suspend weights, these are attached to the keeper, as shown in the figure.

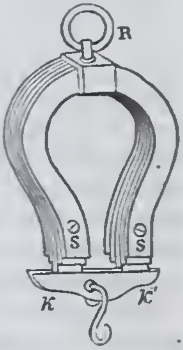
FIG. 3.



21. In order to make a very powerful magnet, a number of single bars are joined together. This makes a *compound magnet*, or a magnetic bundle or battery. They may be either straight or horse-shoe bars. A compound horse-shoe magnet is represented beneath; R is the ring for suspending it, and *kk'* the armature; the bars are magnetised before being joined, and they are fastened with screws *s* and *s* running through them.

22. A piece of loadstone is generally fitted up in a framework of soft iron, and its poles are thus communicated to projecting ends of iron, which have the same action as the ends of magnetic bars.

FIG. 4.



23. The strength of a magnet may be gradually heightened by hanging weights to it, which are to be increased at intervals of time by little and little. On the other hand, the magnet is weakened by abruptly breaking the contact, as in drawing off the keeper suddenly. If an iron bar is in inductive contact with a magnet, and in that position receives a succession

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20. Describe the horse-shoe magnet. What is the keeper? What other names has it? 21. How is a compound magnet formed? 22. How is a loadstone fitted up? 23 How may the power of a magnet be increased or diminished?

of blows with a hammer, it will acquire a fixed magnetism: so, if it is placed under induction while hot, and allowed to cool, the magnetic state will be confirmed so as to remain; also if iron, while under induction, becomes rusty, the chemical action will have the same effect in the magnetism. On the principle that a change in the molecular constitution of the iron can render permanent the magnetic state, it is possible to form an artificial loadstone. On dipping a powerful horse-shoe magnet into iron filings, a great mass will be aggregated round each pole, and they will run together so as to make a string or tuft between the poles. The whole mass taken together will be as one magnet of loose cohesion. If the filings are then moistened with oil, and exposed to a red heat while connected with the magnet, a partial oxidation of the iron will take place. The mass will then cohere together with some degree of compactness, and will remain permanently magnetic, and very much resemble the natural loadstone. On the other hand, a magnet when heated to redness and then cooled, loses its magnetism entirely, as well as its steel temper. Red-hot iron loses the power of being attracted by the magnet, and seems to become like one of the indifferent metals. On closer examination, however, and by the use of a magnet of very great power, Faraday found that the magnetic susceptibility is not entirely lost at a red heat, but merely very much enfeebled.

24. Iron is not the only magnetic metal, although it be the one most powerfully affected. Nickel and cobalt are also magnetic, and are attracted and polarised exactly like iron. It was formerly supposed that all the metals might be subject to magnetism in some degree, although perhaps it might require a much lower temperature than ordinary to make the polarity appear; but the recent experiments of Faraday are tending to show that only a limited number of them are magnetic; namely, the three already decided on—iron, nickel, and cobalt; and as far as appears at pre-

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How may you form an artificial loadstone? What is said of red-hot iron? 24. What metals besides iron are magnetic? What was formerly believed of metals?

sent, six others—titanium, manganese, cerium, chromium, palladium, and platinum; while the rest exhibit appearances of a kind directly opposed to the actions of magnetic bodies.

25. A certain number of metals when under high magnetic influence—as when lying between the poles of a powerful horse-shoe magnet—are repelled by both poles alike, so that a bar suspended between two poles is compelled to assume a cross position, from its seeking to be removed as far as it can be from both. To this action Faraday has given the name of *diamagnetism*, or cross magnetism. It is, however, radically different from magnetic action, although caused by a magnet. Its want of the polar character makes it an exception to all forms of electrical excitement. It takes place so decidedly on the following metals, as to prove them to be at least not magnetic—antimony, bismuth, cadmium, copper, gold, lead, mercury, silver, tin, zinc. But the cross action is not confined to metals: it belongs to almost all solid, liquid, and gaseous substances, excepting those that are magnetic; and it may belong to them too for anything we know, since, though it did exist, it would be overpowered and hidden by their magnetic tendency. The diamagnetic action is found to be strongest with bismuth, phosphorus, and the heavy glass, composed of the silicated borate of lead.

26. When a substance is magnetic, like iron, all its compounds are magnetic likewise. Oxides and salts, and the other combinations of iron, nickel, cobalt, titanium, &c., are all attracted by the magnet, and consequently excluded from the list of Faraday's diamagnetics. Liquid solutions of the acids and salts of these metals are seen to be magnetic as well as the solid masses. Hence if any compound of a metal shows polarity, or is attracted by a magnet, that metal is inferred to be magnetic. It was principally by the use of compounds that Faraday determined the magnetic character of the six metals above enumerated additional to iron, nickel, and cobalt.

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25. What is cross-magnetism? In what metals does it take place? Is it confined to metals? 26. What is observed of the compounds of magnetic substances?

MAGNETISM OF THE EARTH.

27. The earth, taken as a whole, forms a great magnet having two poles, termed its *north and south magnetic poles.* This is proved by the fact, that all magnets assume a fixed position on its surface, in a direction nearly north and south. If we suspend a magnetised bar with a string, and leave it to itself, on coming to rest it will take this north and south direction; and if we move it or whirl it round, it will come to rest again in the same position. The exact direction of the magnetic needle, or freely-suspended bar, in any place on the earth, determines the *magnetic meridian* of that place; which is an imaginary upright plane, (like those used in astronomy,) passing through or along the bar thus suspended. This meridian is not always due north and south, and consequently it does not coincide with the astronomical meridian. Its deviation from the latter is called the *declination.* This declination is sometimes east and sometimes west. It is also called the variation of the compass; and in using a compass to determine the true north point, allowance must be made for such variation.

28. The declination varies in different places, and is constantly changing for any one place. Its change is steady and progressive: after increasing up to a certain point on one side, it decreases, comes to nothing, and passes to the other side, where it increases to a maximum, and then commences to retreat. Thus in 1660 there was no variation in London; the needle lay exactly north and south. In 1700 it had acquired nearly 10 degrees of deviation to the west, which went on increasing in this direction during the whole of last century; and in 1800 it amounted to upwards of 24 degrees. From 1815 downwards it has been slowly decreasing. It must take several hundreds of years to go through an entire course. Besides this general movement in one direction, the needle shows other varia-

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27. How may the earth be considered? How is this proved? What is declination? 28. Describe its variation from the year 1600. What is the diurnal variation of the needle?

tions: it has a small daily vibration called the *diurnal variation.* From sunrise it begins its westerly sweep, which continues till about five P.M.: it then retrogrades, and continues to move east until it has reached its mean position, where it settles through the night. This movement seems connected with the course of the sun.

29. If a bar or needle is made to balance itself level or evenly in an axis before being magnetised, it will not lie even, if placed in the magnetic meridian, after it has been rendered a magnet. It points downward, or is said to *dip.* This dip or *inclination* of the needle is so great in some places as to make it stand nearly upright. But the dip varies with the latitude. On the equator the needle is nearly level; in the regions about the north and south poles it approaches the upright position. In this country it inclines or dips about 70 degrees. It is evidently owing to the earth's magnetic poles being situated deep in the interior of the globe somewhere in the arctic and antarctic circles. Captain Ross came to a place in 70° 5′ north latitude, and 263° 14′ east longitude, where the needle stood perfectly upright, showing that the north magnetic pole was directly under that spot, being thus at a considerable distance from the north pole of the earth. On the other hand, there are places in the tropics where the needle has no inclination; and every such place is said to be in the *magnetic equator*, which is formed by drawing a line through all the points where this perfect level occurs. The magnetic equator does not coincide with the earth's equator, but deviates to each side of it, and forms on the whole a very irregular line. The level of the needle is evidently produced by the equal and opposing actions of the north and south poles. North of the magnetic equator the dip is north, and south of the equator it is south.

30. There is the same constant fluctuation in the inclination as in the declination of the needle. The inclination has been gradually diminishing in London for the last cen-

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29. What is the dip of the needle? Where did Captain Ross discover the magnetic pole? What is the magnetic equator? How does it differ from the earth's equator?

tury. It also has daily variations. The aurora borealis has always an effect upon the magnetic needle, both in its declination and its inclination. Earthquakes and volcanic eruptions are accompanied with magnetic disturbances, which sometimes cause a permanent alteration of the needle. There occur, besides, agitations, called magnetic storms, which sometimes affect a whole continent simultaneously, and produce large vibrations in all the magnetic instruments. From all these circumstances, it appears that the earth's magnetism is undergoing incessant fluctuations and changes, some gradual and steady, others sudden and momentary.

31. Besides the inclination and declination caused by the earth's magnetic polarity, the *intensity* of the action has been made a matter of observation. This is measured by a separate instrument, and it is found to be least on the magnetic equator, and to increase gradually towards the magnetic poles ; but like the other two elements, it is continually varying in the same place.

32. In regard to inducing magnetism upon iron, the earth acts like an ordinary magnet. A bar of iron, pointed to the pole like a dipping needle, and hammered, or cooled, or rusted in that position, becomes a magnet. So certain is this effect, that hardly any iron is ever found free from magnetism. The earth's inductive effect is rendered permanent in pieces of iron by the various modes of working and employing them, as well as by the spontaneous oxidation which occurs when they are lying unused. In high north latitudes, pokers and bars that usually stand on end inevitably acquire a small degree of magnetism. In the tropics, bars which lie on the ground nearly north and south are affected in a similar way.

33. The magnetic force, like all other influences spreading or radiating from a center, diminishes as the square of the distance increases.

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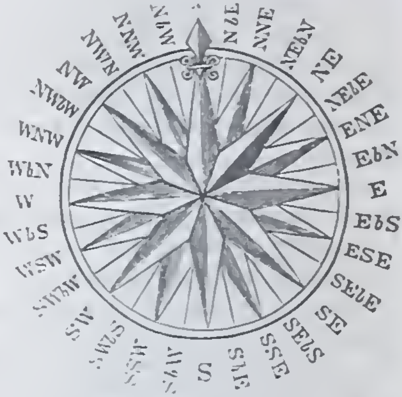
30. What phenomena cause fluctuations in the declination and dip of the needle? 31. How does the intensity of magnetic action vary? 32. When does the earth induce magnetism in iron? 33. What is the law of the magnetic force?

MAGNETIC INSTRUMENTS.

34. The apparatus designed to exhibit magnetic actions, not only serve for the study of the phenomena in a scientific point of view, but have also very important practical applications. The *mariners' compass*, which is a declination needle, serves to guide navigation in the open ocean, when there is no mark either in the sky or on the visible horizon to distinguish north, south, east, and west. By pointing always to the north, or within a known angle of the exact north point, it shows the course of the ship at every moment. The most essential part is a magnetised bar of steel, called the *needle*, which is supported horizontally on a central pivot, round which it is free to move and to point in any direction. The pivot rises from a circular *card* or dial, round the circumference of which are marked thirty-two *points*. The preceding figure represents this card:—North, south, east, and west, are the main or cardinal points, and are indicated by their initial letters respectively, while the subordinate points are also marked by letters, as N *b* E for north-by-east, N N E north-north-east; and so on. To be able to recite the various points is said to "box the compass." The card and needle are fixed in a round *box*, enclosed by a sheet of glass, to secure it both from the agitation of the atmosphere, as well as to exclude dust, moisture, and other things which might interfere with the correctness of its indications. The whole is enclosed in another box, suspend-

FIG. 5.



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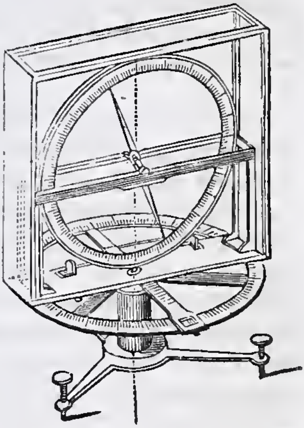
34. What is the use of the mariner's compass? Describe the position of the needle. The points of the card. The hanging of the box. What is it to "box the compass?"

ed by two concentric brass circles or *gimbals*, as they are technically called, and in such a manner that the compass hangs, as it were, on points like a swivel, by which, during the pitching and rocking of the ship, the needle and its card remain in a horizontal position, and under all circumstances of motion indicate the various points correctly.

35. The *dipping* or *inclination needle* has to be suspended on an axis, with an upright graduated rim attached to it, to show the amount of the inclination. The instrument is represented complete in the figure.

FIG. 6.



36. A great improvement has been effected in the use of the compass by taking into account the action of the iron of a ship upon it, and providing a method of neutralising this action, whose effect would of itself render inaccurate the indication of the needle. A ship necessarily contains a large quantity of iron, which is sure to have some degree of magnetic power; and as the compass hangs in the stern, the attraction of the iron will always tend to make the needle turn to the direction of the ship's motion. It has been actually found that this source of disturbance is sufficient to cause very great mistakes as to the courses of vessels. The remedy for it was invented by Barlow, and is called *Barlow's Protecting Plate.* It is a plate of iron, fixed behind the compass, or between it and the stern of the ship, which of itself would produce a disturbance of the needle; but it may be so adjusted that its action shall be exactly equal to the action of the other iron of the ship. Although this counteracting plate weighs only a few pounds, yet, by its nearness to the needle, it can be made as power-

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35. What does the dipping or inclination needle show? 36. How is the effect produced by the iron of the ship neutralised? Describe the method of adjustment.

ful as the whole mass of the ship's metal, whose average distance from the compass is necessarily considerable. The adjustment is made by finding out first the disturbance produced by the vessel on the compass; which is done by comparison with a compass placed out of the reach of the disturbing influence. The plate is then mounted in connection with the compass, and moved farther or nearer till it cause exactly the same amount of error, and the position thus found is made permanent. The ship's compass is taken on shore when this last operation is performed; and a complete neutrality can thus be effected.

THE MAGNETIC FLUIDS.

37. To account for the magnetic phenomena, it has been supposed that there are contained in the structure of iron and other magnetic substances two subtile fluids destitute of weight, color, or sensible appearance, but imparting great energy to the solid matter. A portion of one fluid strongly repels another portion of the same fluid, but strongly attracts a portion of the other fluid. Each atom contains about it a certain quantity of both. In the unmagnetised state, the two neutralise each other, and have no influence of any kind; but by excitement, one fluid is driven towards one end of an atom, and the other accumulated at the other end. Being prevented, by the cause which rouses the excitement, from coming together upon the same atom, through their mutual attraction, they produce attractions between adjoining particles. The fluid accumulated at one end of one atom attracts the opposite fluid at the end of another atom; and as the fluids cannot quit their respective atoms, these are drawn together at their unlike ends. When two atoms are lying contiguous, if one has its fluids excited and polarised, the fluid accumulated at one end will draw the opposite fluid of the adjoining particle towards itself, and repel the fluid like to it (as the moon draws the water in the earth under herself,)

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37. What supposition has been made of fluids in magnetic substances? How are these fluids joined in the atoms of the substance? How will these atoms then act upon each other?

and the second atom will thus be polarised by the inductive power of the first. This second atom will have a like action on the third, and polarity will thus be propagated like waves. Each excited pole will cause an *opposite* excitement in the adjoining side of the next atom, and a *like* excitement in the far-off side.

38. This hypothesis serves in some measure to represent or express the actions which are seen to occur; it cannot be said at all to explain them.

FRICTIONAL OR TENSION ELECTRICITY.

39. The electricity of Friction or Tension is the excitement that first received the name of electricity; and it is still called Common Electricity. It is usually developed by means of friction, although there are many other sources of it. Its most appropriate name is Tension Electricity; meaning that it possesses a high degree of tension, or tightness, or energy, so that when it is discharged, it strikes a sudden and powerful blow on whatever comes in its way. It agrees with magnetism in being a permanent and self-sustaining excitement; it is contrasted with magnetism in its being producible on almost all substances, and in its being very liable to be discharged or reduced to neutrality.

40. If we take a stick of sealing-wax, and rub it with a dry woollen cloth, we shall find that it has acquired the power of attracting light bodies, such as little bits of paper, or fine dust. In its ordinary condition the wax has no such property; the attraction is caused solely by the excitement of the rubbing. A piece of amber, (*electron*,) or any resinous body, will show the same phenomenon. A glass rod, well dried, and rubbed with a piece of silk, will in like manner become attractive for light bodies.

41. The entire range of this action is best seen by sus-

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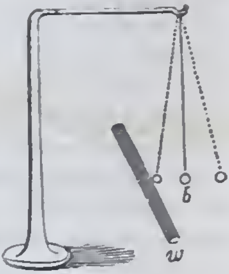
39. How is Tension Electricity produced? In what does it accord with magnetism? In what disagree? 40. How may attraction be produced in sealing-wax? In a glass rod?

FIG. 7.



pending a feather, or a pith-ball, by a silk thread, on a stand such as that in the figure. The lightness and mobility of the ball (*b*) make it a very delicate test of the existence of attraction. If, then, we bring the rubbed wax (*w*) near the ball, it will be attracted; but on the instant of touching, the attraction seems to cease; the ball drops away from the wax and flies off, and is now repelled by it; so that if we bring the wax near the ball, the latter moves still farther away. The contact brought about by the attraction at first has led to the communication of something to the ball, which causes it to be actively repelled by the wax. A rod of glass will exhibit the very same train of actions; first, attraction, then contact, and lastly, active repulsion.

42. If, now, we compare the effects of wax and glass on the same ball, a new distinction appears. Let the ball be acted on by the excited wax, or be attracted, touched, and finally repelled. While in this state of *repulsion* by the wax, let an excited glass rod be brought near it, it is instantly *attracted* by the glass, brought into contact, and then repelled. If the wax be now brought near, the ball will be attracted once more; so that there is evidently an opposition in the characters of excited wax and excited glass; what the one repels, the other attracts, and what the one attracts, the other repels. They are like the opposite poles of a magnet. The friction thus developes a force which is polar in its nature. The discovery of the difference between wax and glass has led to the belief in two kinds of electricity; the one called *resinous*, from its being the excitement of wax and resinous bodies; the other *vitreous*, or the excitement of glass.

43. If we now take two pith-balls, and suspend them together, or near one another, and apply the excited wax,

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41. Describe Fig. 7. 42. Explain the effects of wax and glass on the pith-ball? How many kinds of electricity are considered to exist? What are they?

we find both attracted, sticking for an instant on the wax, and then driven off, and both held at a distance by repulsion; but besides being repelled by the wax, we see that they are also repelled by one another. The very same happens with a glass rod, or any electrified substance; so that when two bodies have touched one and the same excited body, they acquire a mutual repulsion. It is now plain that the balls have received some influence by touching the wax, for after it is taken out of the way, they continue actively to repel one another. From this we infer that a body electrified by friction can communicate its excitement to another body by touching it; so that the excitement does not remain fixed in the place where it was produced, but can run along from one surface to another. This conveyance from place to place is called *conduction.* While the pith-ball lies on the surface of the wax, it receives a portion of the wax's excitement upon its own surface; and when two balls have each acquired excitement in this way, they show it by repelling each other, just as the wax itself repels one or both of them. It is manifest that the electricity that passes upon the pith-ball from the wax, is of the same kind as the wax itself possesses. This can be still better proved by comparing, as follows, the wax with the opposite substance, or with the glass rod.

44. If the glass rod is used exactly as we have described in the case of the wax, the same thing will happen by means of it; the two balls will be both attracted, then both repelled, and when the rod is withdrawn they will remain repelling one another. But let us next act on one of the balls with the wax, and on the other with the glass, until the one ball is seen actively repelled by the former, and the other actively repelled by the latter. In this state let the balls be brought within a little distance of each other; they instantly attract and fly together. Thus when both balls receive excitement from one substance,

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43. What is observed of two pith balls attracted by wax? What is conduction? 44. How do the balls act upon each other when attracted separately by wax and glass?

they repel, when they receive excitement from opposite substances, they attract, one another. The wax by touch gives its resinous excitement, and the glass a vitreous excitement; and the opposition of polarities thus created causes attraction, as in the magnet.

45. We have therefore the following general results arising from the rubbing of substances:—

1*st*, A great number of bodies, by being rubbed, acquire an electrical excitement, shown in attracting other bodies. Both the substances rubbed and the substances attracted may be as various as possible; showing that the property is not special and confined to one or a few substances, like magnetism, but universally diffused.

2*d*, This excitement can be communicated by touch to other bodies; showing that it does not remain attached to the excited particles, but may run along a surface and seize other particles, and give them the same power as if they had been themselves acted on by the rubbing. This property of *conduction* is not seen in magnetism.

3*d*, There are two opposite kinds of the excitement exemplified, the one in wax, and all resinous bodies; the other in glass (vitreous)

4*th*, When two bodies receive the same excitement, they repel each other; when they receive opposite excitements, they attract each other. This is the law of magnetic excitement also.

46. It is found that the force of the attraction, or the repulsion caused by electricity, is inversely as the square of the distance; whence it resembles not only magnetism, but gravitation, heat, light, and sound.

47. It is necessary to state here the explanation given by Franklin of these phenomena, as it led to the adoption of the terms *positive* and *negative*, instead of vitreous and resinous, to express the two electricities. He imagined a fluid pervading all matter, strongly self-repulsive like a highly-elastic gas, and spreading itself as wide as it possibly

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45. Is electricity general, or confined to few substances? How may it be communicated? What is the law of attraction and repulsion? 46. The law of attractive force?

can. This great repulsiveness is, however, modified by its second property, which is an energetic attraction or adhesion to all material bodies, so that each substance contains a quantity of fluid pervading it throughout, and firmly bound to each atom. In ordinary circumstances it is in a state of rest or equilibrium, or so counteracted by itself that it makes no motions of any kind; but when two bodies are rubbed together, the equilibrium is disturbed, one of the bodies acquires more than its natural share, and the other less: the one contains, as it were, condensed fluid or ether; the other rarefied fluid. But this forced inequality cannot last; the condensed fluid tends to rush towards the rarefied portion, and in so doing, drags with it the substance it resides in, so that there is an attraction of the bodies themselves when their containing fluids are of unequal strength. Hence the tendency to come to an equilibrium, joined with the adhesion to the particles of bodies, brings on the attraction which we see. On the other hand, if two bodies have both an access or a condensation of the fluid, their repulsion will be above average, and they will move away from one another.

48. This hypothetical assumption is not sufficient to explain all the phenomena; but it agrees with some of the most prominent of them, and brings out an additional fact, not apparent from any of the foregoing experiments, but completely established by other experiments, which we shall state as the fifth general law of electrical excitement.

5th, When a body is electrified by being rubbed, the rubbing body also receives an equal and opposite excitement. Thus the cloth that rubbed the wax is electrified as much as the wax, but with the opposite kind—that is, of the same kind as glass acquires. So the rubber of the glass rod is resinously electrified.

49. Now, according to Franklin, electrical excitement is the same as an excess or a defect of the electrical self-

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47. What was Franklin's theory of the electric fluid? How does this explain attraction? Repulsion? 48. What is the fifth general law? 49. What two kinds of electricity are distinguished? What reason is given for these names?

repulsive other: and accordingly he calls the one excitement *plus* or *positive* electricity, the other *minus* or *negative* electricity. These terms are found to be so appropriate that they have been retained, and extended to all the *current* electricities to be afterwards described. The electricity produced on glass is what is chosen as positive; that on wax is therefore negative. It is therefore to be distinctly borne in mind that

Glass or vitreous electricity is *positive.*
Wax or resinous electricity is *negative.*

When a pith-ball touches sealing-wax, it is *negatively* electrified; when it touches glass, it is *positively* electrified. The cloth which rubs wax is positive; the cloth which rubs glass is negative. Positively electrified bodies repel each other; negatively electrified bodies also repel each other; a positive body and a negative attract each other.

CONDUCTORS AND INSULATORS.

50. Although the word *conduction* is used to express the travelling of electrical excitement from one surface to another, the passage of electricity is very different from the passage of heat, also expressed by conduction. Heat is conveyed slowly from one portion of a mass to another, or from one body to another in contact with it; electricity passes quickly, and sometimes, we may say, instantaneously. Heat penetrates the interior, electricity travels on the surface. Electricity is not radiant like heat; it does indeed influence bodies which are at some distance, but the influence is quite of another kind from conduction, or from what passes by touch or contact.

51. But although conduction is a general property of the electrical excitement, it is very different for different bodies. On some surfaces the excitement runs from end to end with such quickness that no sensible time elapses; on others it travels slowly, so that a rod might be strongly excited at

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What kind of electricity is positive? What negative? Which kinds attract? Which repel? 50. How does the passage of electricity differ from that of heat? 51. What is a bad conductor? What an insulator?

one end, and yet remain a long time neutral at the other end; such a body would be called a bad conductor. But the word *insulate* is used as the opposite of *conduct;* when a substance retains the electricity, and resists its passage from place to place, it is said to be an *insulator;* the electricity is cooped up there as in an *insula* or island.

52. The substances we have mentioned as convenient for producing electricity—namely, wax, resin, amber, glass, &c.—are all bad conductors, or insulators. The excitement on a stick of wax remains almost on the very spots which are rubbed; it does not pass along the surface except in a very small degree. The same is true of a glass rod, but not to the same extent; the glassy surface resists the passage sufficiently to be called a good insulator, but it does not resist so well as the wax. This property of insulating the electricity is essential to the success of such experiments as we have described with these substances: had the excitement run freely over the surface of the rods, it would have passed away by the hand, and disappeared as fast as it was produced, and the attractions would not have occurred. If the rods were wet, the effects would not be seen; for water in the smallest film is a good conductor, and would carry away the excitement, so that we would not know that any had been really produced.

53. The substances which form the best conductors are the metals. Although unequal in this respect, every one of them is a good conductor; so much so, that no perceptible electricity can remain on any surface, if there be a metal in contact with it and connected with the ground. The following table exhibits a series of bodies in the order of their conducting power: those at the top are the best conductors, those at the bottom the worst conductors, or the best insulators. Read from above downward, it exhibits the order of conducting power; from below upward, it shows the order of insulating power, so that we can give it the one title at the top, and the other at the bottom:—

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52. Are glass and wax conductors, or insulators? If they are wet, can the excitement be retained? Why not? 53. What are the best conductors? How is the table to be read?

CONDUCTORS.

Metals.
Charcoal in its various forms.
Fused chlorides, iodides, and salts generally.
Strong acids.
Alkaline solutions.
Water.
Alchohol.
Damp air.
Vegetable bodies.

. . . .

Animal bodies.
Spermaceti.
Glass.
Sulphur.
Fixed Oils.
Turpentine.
Resins.
Ice
Diamond.
Shell-lac.
Oxalate of lime.
Dry gases.

INSULATORS.

54. It will thus be seen that *charcoal* stands next to the metals; but this holds only of its pure forms, such as plumbago and well-prepared wood charcoal. In coal there is a mixture of oily and pitchy matter, which lowers the conducting power, because these substances stand low in the table. *Fused salts* are good conductors, and next to them salts not fused. *Acid* and *alkaline solutions* are better than *water*. When *vegetable* and *animal bodies* are spoken of as inferior in conducting power to water and alcohol, it is to be understood that they are quite *dry*. Living vegetables and animals are always moist, which will give them almost the same conducting power as water. The best insulators are seen to be the *dry gases;* that is, gases free from steam and vapor. *Water* is a good conductor only in its liquid state; *ice* stands low; and *steam* is not a conductor, but it is so liable to deposit water or dew on

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54. What rank does charcoal hold among conductors? Is this true of all charcoal? What are better conductors than water? What is said of vegetables and animals? What are the best insulators?

the surfaces of bodies, that its presence is generally adverse to insulation. *Shell-lac* is very much used as the best practical insulator; it belongs to the class of resinous bodies, but excels all the others of its kind in this peculiarity. *Glass* stands much below the resins in insulating power, and it is surpassed by sulphur; but on account of its hardness and strength, it has very frequently to be adopted as an insulator.

55. It is convenient to draw a line in the above table at the place where, for practical puposes, conduction ceases and insulation begins. This line is taken between vegetable and animal bodies: a dry vegetable substance, such as a piece of wood or a linen thread, is a conductor, though an imperfect one; a dry animal substance, as a silk thread, is reckoned an insulator, and used as such. The farther we go from these on either side, the respective peculiarities become more intense and decided. For good conduction, a wire of some metal, such as copper, is used; for good insulation, glass, or wax, or shell-lac, may be chosen. But the very best insulators are made conductors by being damp; hence dryness of surface must be carefully attended to. An eletrical eel, brought to this country some time ago, was killed by a water-rat in spite of its electric discharges; which, though sufficient to stun very powerful animals, had no effect on the rat, whose fur is unwetable by water, and therefore, as a dry animal substance, prove a good insulator.

56. The substances presented in the table, are merely a selection from the general mass of existing substances. Every body in nature is either a conductor or an insulator of electricity; but the foregoing list will suffice to show with what other properties a conducting or insulating power is usually combined. It is evident, for example, that the gaseous state tends strongly to insulation; that bodies abounding in combustible material, such as the resins, are insulating; that the presence of water always

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55. What is the object of the line drawn in the table? What effect has dampness upon insulators? 56. What may be said of all substances? Explain how the table generalises a great variety of substances.

causes conduction; and so on. The character of a very wide range of substances is determined since the rank of metals and of vegetable and animal bodies is ascertained.

57. It was formerly considered that the insulators were the only bodies that electricity could be excited on; hence they were also called *electrics*, while the conductors, such as the metals, were called *non-electrics*. But this supposition is false. The metals are excitable by friction the same as the resins; but from their being good conductors, the electricity is apt to disappear from their surface as fast as it is formed. It is possible, by proper insulation, to make them electric, as well as sealing-wax or glass. In the electrical machine, the electricity is produced by the rubbing of a metallic surface on glass. The distinction of electrics and non-electrics, therefore, is no longer admitted.

58. The earth is considered the general reservoir of electricity: whenever any excitement is connected with the ground by a good conductor, it passes thither, and is lost by dissipation, like a wave spreading out on a boundless sea. The earth is generally neutral, or very slightly charged; and electricity of high tension will always run towards a body with either no charge, or with a feebler charge, and still more with an opposite charge. If the earth were negatively electrified, positive electricity would run towards it with still more energy than if it were neutral; whereas negative electricity would not run thither, unless its tension or strength were greater than the tension of the earth's charge. It is in all cases necessary to place insulators between an electrified body and the ground, in order to retain the charge.

59. When an electrified surface, or an electric charge of any kind, has two connections with the ground, or with neutral surfaces where it can spread, it always passes by the best conductor, even although this should be by far the longest path. Thus a metallic rod would be preferred to a line of water, water to dry wood, and wood to glass.

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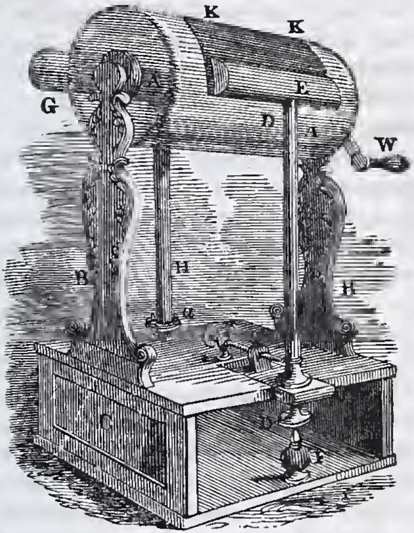
57. What names were formerly given to bodies? Are these names still retained? Why not? 58. What is the earth considered? How can the charge of a body be retained? 59. How will electricity always pass?

THE ELECTRICAL MACHINE.

FIG. 8.



60. In order to procure electricity in large quantities, and of great intensity, a rubbing machine is constructed, called the Electrical Machine. Its essential parts are *a cylinder of glass* mounted on an axle on which it may be turned, a *cushion* covered with a metallic paste, and a *metallc cylinder* to take the electricity off from the glass. The figure represents a machine complete in all its parts. AA is the glass cylinder revolving on an axis in the two supports B and B, which are either of wood or glass. E is a cylinder, carrying the cushion that rubs on the glass. The cushion is commonly separable from the cylinder, and when placed in it, rests on a spring, which keeps it close to the glass during the whirling. The cylinder E has a metallic surface of brass or tin, and it is supported on a pillar D, which is an insulator made of glass. On the other side of the glass cylinder is the metallic cylinder G, destined to receive the electricity evolved on the former. It does not of itself rub on the glass, but it is armed with a row of brass points, which almost touch the excited cylinder, and which are specially adapted to carry off the electricity, and spread it over the metallic surface. This cylinder is called the Prime Conductor, or first receiver of the excitement, and it is supported by a glass

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60. What is the object of the electrical machine? What are its essential parts? Describe the glass cylinder and its position. The cushion. The metallic cylinder. What is its name?

pillar, H, in order to be insulated. As the electricity of glass is positive, this cylinder must always receive positive electricity; hence it is called the Positive Prime Conductor. Since the cushion cylinder gets itself charged with negative electricity, it is called the negative Prime Conductor. The base of the pillar supporting the negative conductor, is moveable by a screw *s s*, to regulate the pressure of the cushion. A flap of silk (K K) is fastened to the upper edge of the cushion, and covers the upper half of the cylinder; this may both increase the friction given to the glass, and help to retain the electricity on the surface till it go round to the points on the prime receiver. The surface of the cylinder and of the insulating pillars must be kept warm and dry during the working of the machine; and for this purpose a permanent heating body is sometimes kept near, such as an iron heater or a lamp (F) applied to the hollow (D) of each glass pillar. Although the cushion cylinder is on an insulating stand, it is not generally insulated when the machine is worked; insulation is used merely for certain special experiments. Accordingly, it is usual to connect the negative cylinder with the ground by a chain. If it were not so connected, it would become highly charged with negative electricity, and resist the further disengagement of the excitement.

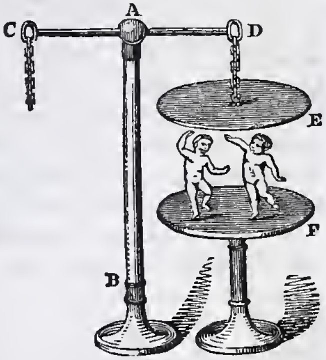
61. The operation, then, consists in turning the cylinder rapidly by the handle W. Its surface is rubbed hard on the metallic paste, which the cushion is smeared with, and electricity is evolved of both kinds. The positive excitement appears on the glass, and is carried round and taken off by the points of the prime conductor, and there accumulated, being cut off from all conducting communication with the ground. The negative excitement is given to the metallic coating of the cushion, and thence to the whole of the negative cylinder; but for the sake of getting additional excitement from the machine to the other side, this is carried to the earth by the chain.

What name has the cushion cylinder? What is the position and object of the flap of silk? How are the cylinders kept dry? 61. Describe the working of the machine. Where is a chain fastened?

62. While the positive prime conductor is thus receiving a constant stream of positive excitement, we may derive from it electricity for any experiments that we desire to make, or we may observe upon itself the various properties of electrical excitement. Such experiments as we detailed at the outset can now be made with far greater effect than with glass rods or sealing-wax; the attractions and repulsions will be much more powerful. Feathers, pith-balls, and the like, will be attracted and repelled with rapidity and vehemence. And by means of metallic rods, electricity can be conveyed to any surfaces we please at any distance.

63. A great number of striking and beautiful experiments can be made by electrifying bodies, and making them display the attractions and repulsions caused by the electricity. For example, in the figure, B is an insulating stand formed of a glass pillar, A is a brass knob at the top of the pillar, and through this nob runs the brass rod C D, which suspends by a metallic chain the metallic plate E. A second plate, F, lies a few inches beneath the first, and rests on a stand which is not insulated. A few light figures of pith or other substance are laid upon the lower plate, and the end of the rod is brought into connection with the prime conductor of the machine, either by touching it, or communicating by a chain or rod, or by being so near that the electricity can fly off to it in sparks. If the machine is now worked, and electricity conveyed off to C, it will run along C D, and down to the upper plate, and remain there, since it cannot go down by the glass pillar to the

FIG. 9.



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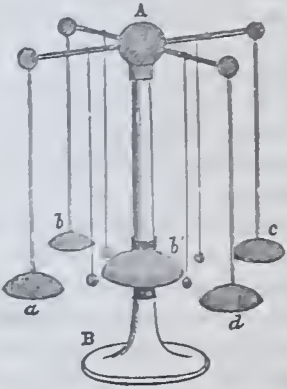
62. With what effect can experiments be made with the machine? Describe the experiment of the dancing figures. What is the cause of their being attracted? Of their being repelled?

earth. The upper plate, in consequence of its charge, will attract the figures from the lower plate, and make them fly up to it; but as soon as they touch, they will become themselves electrified by conduction, and be repelled or thrown down from that plate; but they no sooner touch the lower plate, than they give away their excitement to it, whence the charge passes off to the ground, and they are neutral as before. The upper plate now attracts, and electrifies, and repels them again; and they move up and down a second time, and discharge their excitement to the lower conductor, and are ready to be attracted upwards a third time, and so on. In short, so long as the upper plate is electrified, they are kept dancing up and down; hence the name *Dancing Figures* is given to the apparatus.

64. The *Electrical Bells* is another apparatus for showing the same effect. The stand B carries upon it at a little height a bell *b′*, and above the bell a glass insulating rod terminating in the brass knob A. From A proceeds four brass rods, and from their extremities are suspended by brass rods or chains four bells *a*, *b*, *c*, *d*, hanging on a level with the ball *b′* on the pillar. Four brass balls are suspended by silk threads from the arms running out from A, so as to hang between the outer bells and the central one. Electricity is then conveyed to the central knob, or to any of the arms, and runs over the whole of the arms and the outer bells, but it is prevented by the glass pillar from passing to the middle bell, and by the silk threads from passing to the brass balls. The outer bells are therefore highly charged with the electricity of the positive prime conductor, and each attracts the ball next it. The

FIG. 10.



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64. Describe the Electrical Bells. To what is electricity communicated? How prevented from going to other parts of the apparatus? How is the ringing accomplished?

balls move up, therefore, and strike the bells; but no sooner touch them, than they are repelled, and fly in the direction of the central ball; which, being neutral and uninsulated, takes off their electricity, and with it their repulsion from the outer bells; so that the instant they strike upon the neutral centre, they are again attracted to the electrified bells, and immediately repelled as before. Thus, by incessantly swinging between the two, they keep up a tinkling as long as the electricity continues.

65. Another set of experiments on the same principle is made by feathers, heads of hair, or like bodies. When these are electrified, the repulsion that bodies in the same state always manifest, causes the hair to bristle up, and spread itself out as far apart as possible.

66. It can be easily proved by the machine, that while the glass cylinder acquires positive electricity, the rubber becomes negative. For this purpose the cylinder containing the rubber is insulated by removing the chain usually attached to it, and the positive conductor is connected with the ground. In this state the conductor that has the rubber will be excited, and its excitement can be turned to the same account as the other in such experiments as the above. But to test its character, we must use a suspended pith-ball and a piece of sealing-wax, which we know when rubbed to be negative. Let the sealing-wax attract the pith-ball, and electrify it with its own kind, so as to repel it Let the ball now approach the electrified conductor, which ought to be feebly charged; and it will be repelled by it also, showing that the electricity of this conductor is the same as that of the wax, or negative. If the ball had been excited by touching a glass rod, it would have been attracted by the cushion conductor. Such experiments will not succeed if the conductor is powerfully charged, because in that case the trifling excitement given by a piece of wax is completely overwhelmed by the conductor's excitement, and the ball is acted on as if it were

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65. When hair is electrified, what effect is produced? Why?
66. How is it shown that the cushion of the machine is negatively electrified? When will this experiment fail?

neutral. A piece of excited wax, or any resinous surface, serves on all occasions to test which of the two electricities is produced.

67. The metallic paste smeared upon the cushion (a hair-cushion covered with chamois leather) is what is called an *amalgam ;* that is, a combination of mercury with other metals. If a bar of tin, lead, or zinc, or any metal, be dipped into a vessel of mercury, the mercury will partially dissolve it, like water with a salt A solution in this way of any other metal in mercury gives an amalgam. The mixture used for the electrical rubber is one part of tin and two of zinc to six of mercury ; but different proportions have been used by different experimenters. With the addition of so great a quantity of solid metal, the mercury loses its extreme fluidity, and becomes viscid and pasty, approaching to an incoherent soft powder. It is spread on the cushion with the blade of a knife, and requires to be renewed from time to time ; for besides being dissipated by the action of the machine, it seems to undergo some chemical or other change that gradually takes away its power of exciting the electricity.

68. Another form of the electrical machine, more powerful than the one just described, is what is called the Plate Machine ; that is, instead of a cylinder, a flat circular plate is used. The cushion must then be double, so as to hold the edge as between one's finger and thumb ; and the other parts must correspond to the shape of the glass. Two rubbers and two sets of points are commonly applied to the plate's edge, dividing it, as it were, into four quarters. The objection to such machines is their liability to crack, by the heating that all machines must undergo to make them thoroughly dry before being wrought. But a cylinder machine can be much improved in power by attaching two rubbers to the cylinder, one above and the other below, and enclosing both sides of the cylinder with rows of points. and also by reducing the thickness of the prime conductor (which

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67. What is an amalgam ? What is the composition used for the electrical machine ? 68. What is the plate machine ? How is the cushion formed ? How may a cylinder machine be made more powerful ?

must have the shape of a spur whose arms contain the two rows of points) to about an inch. Such a machine has been constructed by Mr. Straton of Aberdeen; and it yields many times the quantity of electricity that would be given by a machine of equal size made in the ordinary form.

69. A machine of great power has been constructed, which receives the name of Armstrong's Hydro-Electric Machine. It was observed by Mr. Armstrong, that a jet of steam rushing out from an iron boiler, made the boiler give off electric sparks, showing that it had been electrified by this action. Accordingly, iron cylinders have been formed like the boilers of steamboats, and mounted with tubes for the escape of the steam in the form of jets. The steam is raised to a pressure of two or three atmospheres before the tubes are opened. It is then allowed to rush out in a row of jets, and in doing so it communicates *negative* electricity in great quantity, and of a very intense kind, to the whole outer surface of the boiler, while it is itself positively electrified in an equal degree. The boiler being supported on glass pillars, in order to be insulated, becomes so intensely changed that, if not relieved, it darts off sparks to great distances. No rubbing machine can equal such an apparatus in power.

70. The mode of action in this machine has been thoroughly investigated and explained by Faraday. He has shown that the electricity arises from the friction of water globules against the edge of the steam-holes When the steam rushes out at high pressure, it carries a shower of water particles with it, and these act as a rubber upon the metallic surface of the boiler; and the strong friction between water and iron is the source of the electricity. If the steam is dry—that is, if it is perfect steam, or the true, elastic gas of water, and free from cloudy or watery particles—it produces no excitement whatever. If atmospheric air, or any other dry gas is used, there is no electricity excited; and it is completely proved that a gas can in

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How has the power of a cylinder machine been increased? 69. What fact suggested the Hydro-Electric machine? Describe it. 70. What does the steam carry with it in escaping? How do these act?

no case serve as a rubber to evolve electricity. But if the gas carry with it a shower of particles either *solid* or *liquid*, the surface that it rushes through becomes electrified, and the solid or liquid particles acquire the opposite excitement. It depends upon the substance used what is the kind of electricity given to the metal. The iron boiler is made negative by the water particles in the steam current; but if we substitute for water oil of turpentine, olive oil, resin, or other similar bodies, the solid rubbed by them is positive and the jet negative. Either steam or dry air may be used to carry the powder, the gas having no action but to sustain the rubbing stream. The action ceases if the water drops contain any trace of acid or salt, which would render them much better conductors of electricity than drops of pure water. It is from its being too good a conductor, that a metal cannot be electrified by ordinary rubbing, like a piece of amber or wax. But the rapid rush of watery particles succeeds in charging even a metallic surface. If, however, the water is rendered too good a conductor, by an acid or a salt being dissolved in it, the difficulty of keeping the electricities apart is rendered so much greater.

ELECTROSCOPES AND ELECTROMETERS.

71. An instrument for *showing* the existence of electrical excitement is called an Electroscope: an instrument for not only proving it to exist, but also *measuring* its strength or tension, is called an Electrometer. There are many instruments of both kinds:—

72. A pair of pith-balls hung together serve to indicate the presence of electricity. If they are brought into contact with an excited surface, they become both charged with the same kind, and repel each other. Of course, if the surface touched is neutral, there will be no action.

73. The Gold-Leaf Electroscope is on the same principle, but far more delicate. It is represented in the adjoining

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What kind of electricity is given out by the boiler? What will cause positive electricity? When will the steam fail of effect? 71. What is an electroscope? An electrometer? 72. For what may pith balls be used?

FIG. 11.

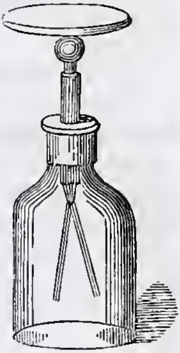
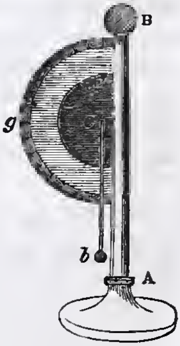


figure. A glass vessel has inserted in it a metallic rod terminating in two gold leaves, and surmounted by a metallic plate. The rod passing through the neck in the bottle is covered with shell-lac varnish, and surrounded besides by a glass tube. A very small degree of excitement communicated to the metallic plate will cause a divergence of the gold leaves. To ascertain the kind of the electricity, it can be compared with the influence of sealing-wax.

74. Both the pith-balls and the gold leaves serve as electrometers to a certain extent; for in proportion to the strength of the charge will be the distance of the repelled balls or leaves. And if we estimate this distance by a graduated scale, we shall have a measure of the electrical tension. But there are many other arrangements for measuring the excitement, such as the following:—

FIG. 12.



75. The Quadrant Electrometer is represented in the cut: A B is the stand, and *g* a semicircle of ivory, graduated according to the divisions of a circle. From the centre *c* hangs a strip of cane, with a pith-ball *b* at its other end. If, now, the stand is connected with an electrical surface, so as to be itself electrified, the pith-ball hanging by it will share in the excitement, and be repelled, and rise up the scale. The degree to which it ascends will be a measure of the strength of the electricity.

76. Volta's electrometer is analogous to the gold-leaf apparatus; but instead of gold leaves, it has two straws hung from hooks at the end of the metallic rod. A scale is fitted up in the glass

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73. Describe the Gold-Leaf electroscope? 74. May it be used as an electrometer? Why? 75. Explain how the Quadrant Electrometer is used. 76. Describe Volta's electrometer. Is this a more delicate measurer than the Quadrant electrometer?

vessel to measure the divergence of the straws. This instrument is much more delicate than the quadrant electrometer.

77. For measuring very strong charges, an apparatus of a larger kind is made use of. Such is what is called the Balance Electrometer, where the strength is measured by the weight which can be overcome by the repellent power of an electrical charge. One end of a rod balanced on the middle lies upon another rod, both ending in balls or knobs; when an electrical charge is communicated to the apparatus, the two balls repel each other, and the end of the balanced rod rises. The weight which can be lifted up by the rising end is a measure of the strength of the charge.

78. The Torsion Balance of Coulomb is a very important instrument, both in electricity and in other departments, for the delicate measurement of forces. A rod is suspended by a thread, so as to hang horizontally like the beam of a balance; and when this rod is acted on by any force, there is no resistance to overcome but its own inertia, and the twisting of the thread; the last is so very slight, that a large sweep of the rod takes place from a very faint action, and thus the minutest degrees of force can be measured and compared. Coulomb invented this instrument to investigate the law of electric force in relation to distance; and by it he proved that electricity resembled gravity and other central forces, and diminished as the square of the distance increased.

INDUCTION.

79. It has been seen that when electricity is evolved, both kinds are formed at the same time. The one of the two rubbed bodies has a positive charge, the other an equally strong negative charge. The same principle extends farther; we find that a charge cannot even exist on a surface unless there be on some adjoining surface an equal and opposite charge. Positive electricity cannot be

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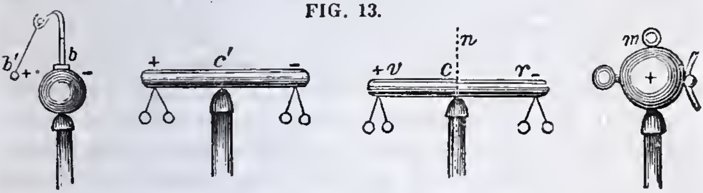
77. For what is the Balance electrometer used? Explain its manner of operation. 78. Describe the Torsion Balance What important law was proved by it? 79. How do the two kinds of electricity exist in matter?

insulated, and made to remain by itself; it will not pass into any situation where it cannot be accompanied with a counter charge of negative excitement. The polar character is rigorously sustained in frictional electricity, as well as in magnetism; we can no more have one kind of excitement alone by itself, than we can have a magnet all north or all south.

80. When a surface charged with electricity of one kind is in the neighborhood of other surfaces, but not touching them, it communicates to them the *opposite* electricity. The apparatus best adapted for demonstrating this is a set of brass cylinders rounded at the ends, and placed on insulating stands.

FIG. 13.



Thus let *m* be the prime conductor of a machine; *c* and *c′*, two insulated cylinders laid end to end at a little distance from each other and from the conductor; and *b* a brass ball, with a pith-ball *b′* suspended to it. When the machine is wrought, the whole of the surface of *m* has positive electricity. Now the action of *m* upon the adjoining cylinder is such, that the nearest end *r* is electrified negatively, and the remote end *v* electrified positively. The cylinder has received no electricity by conduction; it has become polarised by induction, exactly as happens in magnetism. The middle *n* is neutral, and the two ends are charged with equal and opposite excitements. But this cylinder exerts its action on a second cylinder in the same way; the end of which next *v* is negatively charged, and the other end positively charged. The ball *b* also is affected by the positive end of the second cylinder, and made negative at one side and positive at the other, where it repels

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80. What is the object of Fig. 13? Explain how the electricity passes from one cylinder to another. By what power does the conductor communicate electricity? What limits the number of cylinders?

the pith-ball. Thus the prime conductor, without parting with any of its excitement by *conduction*, polarises a series of bodies by its *inductive* power. There is no limit to the number of bodies that might thus act on each other, except the tension of the conductor; but the action on each successive surface becomes gradually feebler.

81. If the remote end of one of the cylinders is connected by a conductor with the earth, the charge on that end passes off to the earth, and the opposite electricity spreads over the whole surface of the cylinder. Thus if the positive excitement of v, the far end of the first cylinder, were conducted away, the cylinder would possess all over a negative charge, as if it had been connected with the negative prime conductor of the machine. But if, on the other hand, without conducting off any portion of the induced electricity from any of the surfaces, we withdraw the prime conductor m, whose tension caused the succession of polarities, they all instantly return to their original neutral condition. The presence of the primitive source is necessary to sustain the action; and when this fails or is cut off, it is like the removal of a magnet from a soft iron bar—the temporary excitement ceases.

82. We may now understand why an electrified surface attracts a neutral or unelectrified body, such as a pith-ball. It is not that electricity causes attractions between excited and unexcited bodies, the same as between bodies oppositely excited; but that the pith-ball is first rendered opposite by induction, and attracted in consequence of this opposition. A pith-ball at a few inches distance from an electrified surface, is charged with electricity by induction; and the kind being contrary to the kind of the surface, attraction ensues; when the two touch, they become of the same kind by conduction. The case of attraction by excited surfaces is the same as the magnet's attraction for iron; an opposite excitement is first communicated to the body, and it is then attracted. If a series of cylinders were elec-

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81. If the end of a cylinder is connected with the earth, what results? What if the prime conductor is removed? 82. Why is a neutral body attracted? What attracts in an analagous manner?

trified as above shown, they would all tend to attract each other by their opposite poles.

83. It is a fact only lately discovered, that neither the prime conductor of the machine, nor any surface whatever, can receive or contain electricity, unless there be other surfaces near to contain an opposite charge of the induced kind. Whatever bodies are in the neighborhood, the walls and furniture of a room, &c., are made use of for this purpose, as well as anything that is casually brought near. If the surrounding surfaces are easily excited, and can take on the induced electricity well, the prime conductor of the machine, or any connected surface, may acquire a high charge; but if these surfaces are difficult to excite, if they are of the non-conducting kind, the prime conductor will receive only a feeble charge. The second pole is in this case not readily observable—it has a sort of irregular character; but decisive experiments were made by Faraday, which proved that where there is not a confronting surface for the induced charge, it is impossible by the most powerful machine to put the least possible excitement on any surface whatever. It had previously been shown, that if the outer surface of a hollow sphere were charged, no electricity would pass to the inside, although there were a free communication by holes; and Faraday put the thing to the test on a large scale by constructing an insulated room, which he went into with his electroscopes, while the outside was charged by a large machine; whereupon it was found that no trace of excitement appeared in the inside. The reason is, that there is not room in the interior of a continuous hollow surface for both excitements to exist apart, and yet confront one another.

84. There is a limit placed to the accumulation of electric excitement on any surface. But the better the opposition surface given for the induced electricity, the higher the charge that it is possible to communicate. Accordingly an apparatus was devised last century by a Dutchman of

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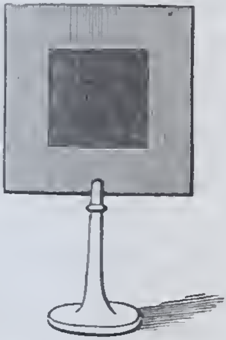
83. What is necessary that a body may receive electricity? To what will the strength of the charge be proportional? What experiment was made by Faraday?

Leyden, thence called the *Leyden jar*, which completely suits the polar nature of the charge by providing two equal surfaces, held apart by an insulating medium, to receive both the primary and the induced electricity. The simplest form of this double-surface apparatus is a pane of glass, with a coating of tinfoil on each side, the coatings being equal to one another, and smaller than the glass, so as to leave an uncoated margin all round, as represented in the figure. If one of the coatings is connected with the machine, and positively charged, it will act by induction through the glass upon the other coating, and excite it in the manner already described in the case of the row of brass cylinders. The near or inner surface of the second coating will be made negative, and the other surface positive; and if the coatings are insulated, this state will continue. But if the outer side of the second coating is connected with the ground, and the positive induced charge taken off, the surface will have only a negative charge left, corresponding to the positive charge of the first coating, directly derived from the machine. We have thus a true polar charge, a positive and a negative surface separated by an insulating medium. The excitement is now no longer *free*, but *fixed*; neither of the electricities will run off by touching the coating with a conductor: they are, as it were, held locked in one another, and the apparatus is almost like an unexcited body. There will be no attraction of pith-balls, because the electricity does not need surrounding surfaces to act upon by induction in order to maintain itself. A very high charge can now be administered, if we keep the outer surface of the second coating connected with the ground, while the first is connected with the machine. There being a proper surface for the induced excitement,

FIG. 14.



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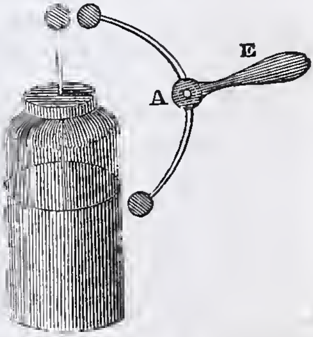
84. Describe Fig. 14. If one coating is charged, what effect will be produced on the other? If the outer surface of the second coating is discharged, what will be the result?

the primary excitement can rise higher and higher; but it will not show its strength in the same way as on a single surface. The dead lock of the two prevents them from acting singly; and we hardly know of the accumulation that has arisen, till the two surfaces are connected by a conductor, such as a metallic wire; we then see a bright spark, and hear a sharp snap, as if a violent shock had been sent through the apparatus.

85. The Leyden jar is a glass bottle with two coatings of tinfoil, one outside and the other inside. The coatings do not reach to the mouth of the bottle, so that they leave a rim of naked glass. A plug is fitted tightly into the mouth, and covered with varnish, and through the middle of it a brass rod is passed, with a chain hanging to its lower end, to make a connection with the inner coating. The upper end of the rod is formed into a round knob. The figure represents the jar with the apparatus used for discharging it; which last is a glass rod E to hold in the hand, and two brass arms connected at A by a movable joint. Through these two arms the two electricities run to meet one another, when one end touches the outside of the jar, and the other comes near the knob connected with the inside. In using the jar it may be held in the hand, and the knob presented to the prime conductor of the machine; the inside thus acquires a positive charge, and induces a negative one on the near surface of the *outer coating* fronting it; that is, on the inside surface. The outside surface of the outer coating would then be positive; but it being in the hand, the positive electricity passes away, and leaves the outer coating entirely free for a negative charge, which

FIG. 15.



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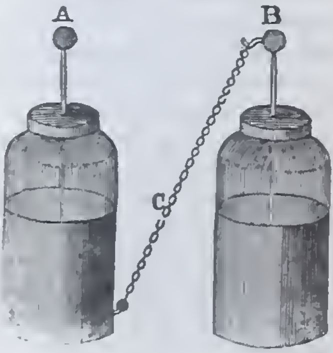
85. Describe the Leyden jar. The apparatus for discharging it. How is the discharge effected? How does the positive electricity pass from the outer surface?

it thus possesses, and thereby fixes the positive charge in the inside. The transmission of more electricity from the machine to the inner coating, induces more on the outer, till the jar is as highly charged as the strength of the excitement communicated can make it. If, now, we try the outside with a pith-ball or other electrometer, we find no sign of electricity; if we try the inside through the projecting rod, we find indeed a very feeble charge; but there is no appearance corresponding to the actual excitement held by the two coatings. Let us next apply the discharging rod; and having touched the outside with one ball, let us approach the knob with the other; and while these are yet an inch or two inches apart, the two electricities will flash together with the usual spark and noise. The tension or strength of the excitement is shown by the distance that may thus be broken through by the attraction of the opposite states for one another; just as the strength of the excitement of the prime conductor of the machine is judged of by the distance that sparks will pass through to a conductor placed near.

86 The electricity driven off from the outer side of the outer coating by the induction, instead of being conveyed to the earth, may be passed to a second jar, and may communicate to it a charge by the same process as the first jar is charged. Thus, in the figure, let A, the knob of the first jar, be in contact with the prime conductor of the machine, and let the outer coating be insulated, by resting the jar on a plate of glass or other insulating substance. A chain C passes from this outer coating to B the projecting rod of the second jar, whose outside com-

FIG. 16.



When the jar is fully charged, is the excitement evident? By what means is its strength shown? 86. How may a second jar be charged from the first?

municates freely with the ground. By working the machine, the inside of the first receives a positive charge, which excites a negative state in the outer coating, and in consequence drives off positive electricity by the chain C to B, and thence to the inner coating of the second jar. A second induction now takes place; and in order to render negative the outer coating of this jar, positive electricity must be driven off to the ground. Thus both jars are charged, and in the same way a succession of jars might be charged; but the second is weaker than the first, and the third than the second, and so on, until at last the excitement would be imperceptible. After being charged, the jars may be disconnected, and each discharged by itself. It happens in this case, as with the cylinders, that one polarity is but the commencement of an endless series of polarities which can be traced to a certain distance, growing weaker and weaker at every step.

87. The strength of charge which can be communicated to a Leyden jar depends upon the thinness of the intervening glass. The whole *quantity* of the excitement will, of course, be greater as the jar is larger in size; but its tension, strength, or intensity increases as the thickness of the glass is reduced. The glass offers a certain resistance to the induction, and a certain degree of tension is expended in overcoming this intermediate resistance. The particles of glass are themselves successively polarised, and it is only the surplus of the inductive power that reaches the other coating. Hence the charge on the second coating is never equal to the charge on the first; and consequently the reaction of the second does not suffice to fix the whole of the excitement of the other. This is the reason why a certain amount of free electricity may be detected in the coating that was connected with the machine. If, however, this free electricity is taken off, the remaining quantity will become insufficient to support and fix the whole of the induced charge in the other coating, and a small

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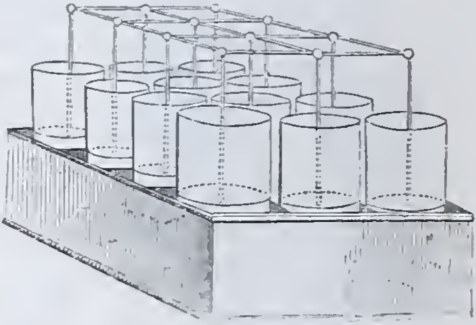
Which kind of electricity is communicated to the second jar? How do the charges of the different jars compare in strength? 87. What relation does the glass of the jar hold in induction?

portion of its electricity will now be rendered free, and become sensible to an electrometer. Should this also be conducted off, the inner side will next show a surplus; and by touching the two sides alternately, the whole charge may at last be taken off, from this constant necessity for there being a surplus on one side to fix the entire charge of the other. The thickness of the glass gives rise, besides, to what is called the *residual* charge; for after discharging a jar, if we apply the rod again, a second discharge of a feeble kind will be observed. The first discharge neutralised the electricities of the metallic coatings; they being good conductors, their portion ran off first, and came together before the excitement of the glass had time to go off; and this remaining excitement furnishes the second discharge. There must be a limit to the thinness of the glass of the jar; for the electricity in polarising its particles evidently tends to tear them out of their natural cohesive position, and to join them together by new sides, corresponding to their electric poles. When the strength of the excitement comes up to a certain point, it forces its way through by making a hole in the glass. Jars are often pierced in this way and rendered useless by the violence of the polar coercion of their particles overcoming their cohesion.

88. In order to accumulate electricity in great quantity, a series of jars are joined together, forming a *Leyden battery*. All the insides are connected by joining their projecting knobs together, and the outsides are connected by passing wires round them from one to anoth-

FIG. 17.



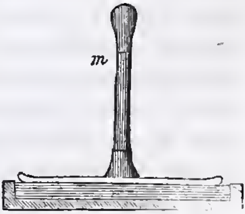
How may the charge of the jar be taken off? Explain the principle of this. What is the residual charge? From what does it arise? 88. How is a Leyden battery formed?

er, or resting them all in a continuous metallic bottom. The principle of the charge is the very same as for a single jar; and the effect is nearly what would follow from one enormous jar whose extent of coatings is equal to the sum of the whole.

89. The insulating substance which separates two conducting surfaces, and enables them to sustain opposite states, is called by Faraday a *Dielectric*. All insulators are dielectrics, and the best insulators are the best dielectrics; for in as far as the dielectric is a conductor, it allows electricity to pass through in its own kind to the opposite surface, and thus discharges instead of charging the apparatus. As the glass of the Leyden jar is not a perfect insulator, but admits a very slow conduction of electricity, the charge necessarily decays, and becomes at last extinct. With sealing-wax or shell-lac the insulation would be more perfect, and the induction better sustained.

90. The action of bodies in the capacity of dielectrics teaches us the cause of their being insulators or non-conductors. Electricity passes through bodies by polarising their particles one after another; but in a good conductor the polar state is very readily induced, and exceedingly little inductive power is expended in bringing it on. Thus suppose the first particle becomes positive on one side, and negative on the other, it finds the second so easy to induce into a positive and negative state in its two sides, that without any loss of tension or time it polarises it; and in the same manner the negative end of the second renders positive the adjoining end of the third and the further end negative. Conduction is supposed to be nothing but a series of inductions; but these in some bodies are easily effected, in others with difficulty.

FIG. 18.



91. The *Electrophorus* is a very useful piece of electrical apparatus,

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What is the principle of the charge? The effect? 89. What is a dielectric? What results from the glass of the Leyden jar not being a perfect dielectric? 90. How does electricity pass through bodies?

depending upon induction. It consists of a plate of metal, covered, but not to the edge, with a plate of resin, which is poured on it and spread out in the melted state. On the cake of resin is placed a second metallic plate having an insulated handle (*m*). If the resin be excited by rubbing, it will have a negative surface; and by laying on the cover, it will be electrified by the contact; the lower surface lying on the resin will be positive by induction, and the upper surface negative. If we touch the latter with a conductor, such as the finger, its negative charge will be taken off, and positive excitement diffused over the whole. By this apparatus a small positive charge can be easily obtained at any time.

92. The *Condenser* of Volta is an instrument intended to accumulate electricity, when of a very feeble strength, such as what arises in chemical actions. It is analogous to the Leyden jar, or rather to the coated pane of glass. It consists of two metallic plates placed on one another, with a very thin layer of gum-lac varnish between them. The thinness of the gum-lac, which serves as the dielectric, allows the induction to pass through, even although the excitement be very feeble; and therefore there can be an accumulation of weak electricity in the same way as the Leyden jar accumulates intense electricity. The condenser serves as an electrometer and electroscope, to attest the presence of excitement when too faint to show itself without accumulation.

93. When a single surface, such as the prime conductor of a machine, is charged by the help of the surrounding surfaces which serve to sustain its inductive charge, the intervening air is the dielectric; but this dielectric is easily overcome or ruptured, so that a discharge can take place through it at great distances. Thus if we hold our knuckle within an inch or two of the conductor, when the machine is at work, the hand serves as one of the random surfaces for the conductor to exert its induction upon, and becomes

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91. Describe the Electrophorus? What is done after exciting electricity in it? 92. Describe the Condenser of Volta. For what is it used? 93. When is the air a dielectric? Relate how its influence may be broken.

strongly negative, and the whole intervening air is polarised like the glass of the Leyden jar; but the air very soon gives way, and allows the opposite excitements to flash together in a spark. The more rarefied the air, the greater the distance that sparks will go through from one surface to another.

94. In the case of an excited single surface, it is found that unless it be a ball, the excitement is not equal on all parts of the surface. The prime conductor is generally a cylinder rounded at the ends into hemispheres, and the electricity is always stronger on the ends than on the body of the cylinder. If we take a large globe and a small one, and join them together by a rod, and pass electricity upon them, the charge will be most intense in the smallest. If the one have four times the surface of the other, the excitement of the large one will have only one-fourth of the strength of the excitement in the small. Whenever a surface approaches to a point or an edge, the intensity proportionally increases. The cause of this unequal distribution is found in the theory of induction:—

We have seen that without a confronting surface to sustain an opposite charge, no body can possibly receive excitement; and the better provided a body is with a surrounding surface, the greater the charge that it can take on. Now, if we have two unequal balls in the same rod, their excitement depends upon the induction which they can exert on the surfaces about them; but the small ball being in the same room as the large, it has as good and extensive an inductive surface presented to it as the other. The two have unequal surfaces of their own; but they have the same confronting exterior surface in the walls and furniture of the room, and on this unequal proportion of surfaces depends their unequal capacity of being excited. If we had twelve balls of different sizes, all strung on one rod, and hung in the middle of a room, they would take on exactly equal charges; but if we had one ball in one room,

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94. What is the usual shape of the prime conductor? Of two electrified balls which will be most strongly excited? Explain this phenomenon by the theory of induction.

and another in a different room of other dimensions and material, the charges would probably be unequal—the ball that found most facility in polarising the surfaces around it would take on the highest excitement. Now the rounded end of a cylinder is acted on like a small ball; for a larger surface is confronted with it than with an equal portion of the body of the cylinder. Suppose that, in the latter, four square inches had such a degree of curvature as to be opposed to one-tenth of the whole surface of the room, and that four square inches on the end made a hemisphere and confronted half the room, (as the surface of a whole sphere would confront it all round,) then the intensity on the end would be five times that on the middle. Accidental arrangements will make one part of a surface more intense than other portions equally well curved and exposed to surrounding surfaces; a metallic plate, for example, lying near one end of the prime conductor, will cause that end to bear a higher charge. A prime conductor of a machine working in a tinsmith's shop, would rise up to much more intensity than in an ordinary sitting-room. If a metallic cylinder were enclosed in a larger cylinder, it might be charged to a considerable degree; for this would be to make a perfect Leyden jar instead of the very imperfect way that the second surface is furnished by the walls and furniture of a room. The obstacle to the charge in this case would be the weakness of the dielectric; we would find it necessary to make the outer cylinder considerably larger than the inner, to allow some thickness to the intervening air, otherwise the electricity would break through and discharge itself.

95. We may now understand the cause of the very great intensity of the excitement at points and edges, and the tendency that the electricity has to pass off from them. A point is a very small surface, confronted with a very large exterior, and the extent of the induced surface allows a very high intensity to be attained. This intensity favors the discharge by increasing the action upon the dielectric

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Which will confront the larger surface, equal areas of a cylinder, or of a ball? What accidents may cause the same surface to be unequally electrified? 95. Why does electricity tend to pass from a point?

of air, so that the electricity will pass off from a point to an opposite body at a much greater distance than it would pass through coming from the round bulge of a large blunt cylinder. Hence if a surface is armed with points, these will rob it of its excitement, and probably disperse it by their discharging force. A row of points are used, as we have seen, to take up the electricity from the cylinder of the machine; they being as powerful to receive excitement from a surface where it is in excess, as to pass it off to a surface where it is deficient. Of all single surfaces, a flat plate will take on the least intensity, and a sharp point the greatest. It is therefore necessary that surfaces which are intended to retain electricity should be well rounded, blunt, and smooth. And on the same principle it is requisite to keep the electrical apparatus free from particles of dust, which, like points, take on an intense charge, and fly away with a large share of the excitement.

THE DISCHARGE.

96. The Leyden jar is discharged by establishing a conducting communication between the two surfaces. But though this is essentially the manner of the discharge in all cases, it usual to reckon three varieties of circumstances wherein it may happen, making, as it were, three different modes of annulling the excitement. These are called, 1*st*, The *conductive*, 2*d*, The *convective*, and 3*d*, The *disruptive* discharges.

1*st*, The *conductive discharge* is exemplified in the slow discharge of a Leyden jar through the glass, which, not being a perfect dielectric, allows of conduction to a small degree. Also when the air between an excited single surface and the surrounding surfaces is damp, the line of watery particles causes a slow communication by conduction, which gradually discharges the excitement. Again, if the uncoated glass of the Leyden jar is damp, a gradual discharge of the same kind takes place.

What surface is susceptible of the least intensity? What of the greatest? Should the electric apparatus be free from dust? Why? 96. How is the Leyden jar discharged? How is the conductive discharge effected?

2*d*, The *convective discharge* is exemplified when pith-balls are attracted and repelled by a conductor, and then by touching some distant body lose their charge and become attracted again, as in the electrical bells and dancing figures. In this case the ball acquires by contact a certain amount of charge, which it carries off and communicates to the opposite induced surface, serving as a go-between to carry positive electricity to the negative surface, and negative electricity to the positive, and bringing about in this way a neutrality or equilibrium. Particles of dust tend to discharge surfaces by this process. In like manner particles of air are set in motion, and convey the electricity from one surface to its opposite. The intense action of points generally causes a current of charged air to run out from them, whose place is supplied by other air that acquires a charge in its turn, and is repelled like the previous portions. There is always a repulsion created by the passage of electricity from points, which can be made use of to create a rotatory motion, by making a sort of wheel with wire spokes, ending in points all bent inwards in one direction, and the whole revolving on an axis. The action is not unlike the force in Barker's mill. (See HYDRAULICS.)

3*d*, The *disruptive discharge* is the breaking or forcing of the dielectric, as when the glass of the Leyden jar is broken through. This arises when the twist given to the particles by their electrical state is stronger than their mutual cohesion. Glass is generally able to resist such a power, but the air offers very little resistance; hence disruptive discharges readily occur in it. This discharge may be exemplified by placing a card between one of the balls of the discharging rod and the coating of a Leyden jar, and passing the electricity through the card; the opening which it forces can then be seen, and from it we may form some idea of the action that has taken place. The hole is very small, such as would be made by a fine needle; but it is widened on both sides, as if the force had come equally

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How do pith-balls or dancing figures tend to produce neutrality? What is this discharge called? In what does the disruptive discharge consist? Illustrate this.

upon it from each coating. Whenever any bad conductor, such as a piece of wood, is put in the way of a discharge, it is split up or pierced in the same manner, if the charge is sufficiently powerful.

97. The disruptive discharge is always accompanied with a flash of light. This has various shapes, according to the conductors used. Between two good conductors of rounded or blunt surfaces—such as the ball of the discharging rod, and the side of the jar or its nob—we have the *spark*, which is a round ball or globule of light, which passes somewhat zig-zag from one to the other. This corresponds also with the most concentrated and energetic form of the discharge. The distance over which the spark will go, disruptively through the air, depends upon the force of the charge, and the goodness of the conducting surfaces between which it runs. From a point, or between a good and a bad conductor, the electricity, passing off, produces a *brush* of light spreading out from a center. The convective discharge through the air yields in the dark a *glow*. When the air is rarefied, the discharge is made easier, and will pass over a greater distance. In an exhausted receiver it will pass through two or three feet in a lambent aurora flame. In the perfect vacuum light is seen, showing that empty space may take on an illumination. "The spark is very bright in condensed atmospheric air, white and intense in carbonic acid gas, red and faint in hydrogen, yellow in steam, and of an apple-green color in ether and alcohol." By laying on a glass plate stripes of tinfoil or gold leaf, cut across and separated at every inch or short interval, and passing electricity through the whole, there will be a disruptive discharge, and a spark at every break of the continuity, and the entire metallic line on the plate will be illuminated. A great many striking effects of a similar kind can be produced in the dark from the electric light.

98. The concussion given to the air by the shock makes

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97. Describe the appearances of the spark or flash that attends the disruptive discharge. How does it appear in different substances? What will occur on passing a charge through tin foil?

the sound that we hear, which is like the sharp crack of a whip. Both the intermediate air and the surfaces discharged are severely agitated by the sudden return from their electrified to their natural state.

99. There is a very perceptible sulphurous smell accompanying the discharge of electricity. The cause of it has been traced by Professor Schonbein to a peculiar substance formed during the discharge, to which he has given the name of *ozone;* and he has shown that the same substance is produced in other ways, and has certain remarkable properties, such as the power of bleaching cotton, like chlorine.

100. Electrical discharges have an acidifying tendency—that is, they form acids when the requisite ingredients are present. Thus nitric acid is sometimes produced in the air by the agency of atmospheric electricity; and alcoholic liquors are turned sour, or made to pass into the acetous, or vinegar fermentation.

101. When the discharge is interrupted by an imperfect or inadequate conductor, it tears, splits, heats, and sometimes sets fire to bodies. Very thin wires are melted; combustible substances, such as phosphorus or gunpowder, are inflamed. The human body feels a violent stunning blow when a charge is sent through it; a very strong charge may cause irrecoverable blindness, or even instant death. A Leyden battery of twelve jars could receive a charge sufficient to kill a man; and accidental deaths have actually occurred in working with such gigantic batteries.

ATMOSPHERIC ELECTRICITY.

102. Franklin had the glory of discovering the identity of electricity and lightning. By putting up a kite while thunder clouds were floating in the sky, he actually drew down by the string a distinct charge of electricity.

103. It is as yet very imperfectly known by what method the electricity of the sky is generated or excited. It is of

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98. What causes the sound attending a shock? 99. What the smell? 100. What effects are produced on liquids? 101. On imperfect conductors? 102. What discovery was made by Franklin?

the same character as frictional electricity, or that of the common machine; but no friction appears to be used in creating it, nor any other method which we are distinctly aware of as capable of producing electricity of high tension. It is certainly produced by heat as the remote cause, but the precise way in which the heat operates is but partially understood. It was supposed at one time that evaporation evolved electricity, but this is found to be a mistake. Evaporating water yields electricity only when some chemical change goes on at the same time, or when it produces some indirect mechanical action, such as the friction of the water particles in Armstrong's machine. But the relation of the electricity of the air to heat is decisively confirmed by the increase in its amount as we pass into the warm latitudes, where thunder-storms appear with a power and grandeur unknown in cold climates.

104. The great constant fact respecting atmospheric electricity is, that the earth is always becoming negatively charged, while the air, or all conducting substances contained in it, is at the same time positively charged. In fine weather this goes on without interruption, but it is different for different hours of the day. When the state of the air is steadily observed by an insulated conducting rod, we find that it is least charged at eight in the morning, and most between eight and ten in the evening. In foggy weather the states are reversed, and the air is generally negative. During an actual shower the air is commonly positive, but the rain-drops themselves, when examined, are found to be in an opposite state. But during showers, and especially during thunder-storms, the state is constantly changing from one kind to the other. The dense fogs which sometimes settle over a place, and last for hours, have usually a strong negative character; and their being thus highly charged with electricity, seems to prevent them from being dissolved by heat so readily as vapors usually are; for it has been observed that a cold fog enter-

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103. What is the character of the electricity of the sky? How is it known to be increased by heat? 104. With which kind of electricity is the earth charged? The air in different states?

ing a warm room will remain for a considerable time in the visible form.

105. The ordinary action taking place upon the air will therefore render all floating clouds liable to become negatively electric, especially in the lower regions, if we suppose that it is at the surface of the earth that the electricity is generated. If other clouds float above, with a stratum of dry air between, these may become positive by induction, and thus there will be an opposition of states among the clouds themselves, as well as the opposition between the lower strata and the earth. When the accumulation has reached a certain pitch, it will be discharged in some one of the three ways. If there is a communication of moist air between the two charged clouds, or between a cloud and the earth, it will pass off quietly by *conduction;* if there is a great movement among the clouds themselves, it may be neutralised by *convection;* but if two contiguous masses are highly charged, and a dielectric of perfectly dry air lie between, there will be a disruptive discharge in the form of thunder and lightning. When two clouds are mutually discharged in this way, the whole commotion takes place in the upper air; the lightning is faint and diffused; and the thunder always distant. But when a large mass of positive cloud hangs over the negative earth, and when the intervening air is dry, and the accumulation great, the discharge bursts forth between the sky and the ground, and is then the most terrific and dangerous. The light has the zig-zag known by the name of forked lightning; and it is apt to be concentrated in some one spot, which is scathed and scorched by the stroke. The thunderbolts which throw down or set fire to houses, shiver trees, and destroy life, are of this character. All the effects capable of being produced on the small scale by electrical jars and batteries, are caused in the grand scale by these thundery discharges between the clouds and the earth.

106. On the principle that electricity always chooses the

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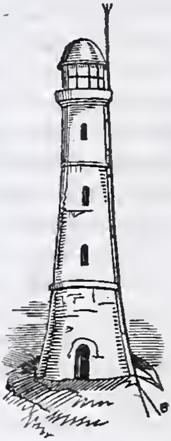
105. When will electricity in two clouds be discharged by conduction? When by convection? When by disruption? When is the lightning faint? When dangerous?

best conductor within its reach, Franklin constructed the thunder-rod for protecting buildings. It is a rod of iron or copper from half an inch to an inch in diameter, rising above the highest pinnacle of the building, and extending down along a wall to terminate in the ground. To receive the excitement more easily, it is pointed at the upper end, or divided into several branches, each ending in a point (see fig.) All pieces of metal on the roof should be connected with the conductor, otherwise these might attract the discharge ; and they not being continued to the ground, it must pass from them to the imperfectly-conducting stone and wood, and produce its destructive effects. When a house has a metallic roofing, or whether it has or not, strips of lead should be built into the walls, and connected with one another, and with all the metallic masses of the house, so that wherever lightning strikes, it may find a metallic conductor near to convey it harmless to the ground. The rod ought not to terminate in a dry conducting body, but be conveyed if possible to moist earth (*e*), or to a well, so that the electricity may be at once discharged into a good conducting medium,

FIG. 19.



107. For the protection of ships, a continuous metallic line is necessary from the mast-heads to the sea. But the conductors in this case must be suited to the changes that have to be made in the masts and rigging during the vicissitudes of a voyage ; hence they are made into a chain, or formed of thin flexible strips of copper.

108. If a thunder-storm strike on a house that has no metallic protection, it will choose in preference bell-wires, damp walls, or gilded pictures ; a human being will be preferred to dry walls or floors ;

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106. Describe the thunder-rod ? What should be connected with it ? Where should it terminate ? 107. How are conductors for ships made ? 108. What about a house will lightning choose ?

hence the danger of such a visitation. But the wooden floors are better conductors than wollen cloth or feathers; hence people lying in bed in the middle of a room are likely to escape. The greatest risk is incurred when a good conductor is afforded so far, and then cut short, and an insulating substance succeeds: the lightning is thus attracted and conveyed a certain way with ease, but has then to force its passage by violence, or by going out of its course, to meet in with some tolerable conductor. The human body, from its moist state, stands high in the list of conducting substances, and would be preferred to a great many other things.

109. It is dangerous to stand under the trees in thunderstorms. A tree is a slightly better conductor than a human body, and would receive the discharge in preference; but the very fact of its attracting the lightning, while it is not a sufficiently good conductor to carry it quietly to the earth, is a reason for not standing near it. The tree itself may be shivered to pieces, and a portion of the shock besides communicated to other objects. In a forest, where there is a large mass of intervening matter, living beings may pass unharmed.

110. For making observations in atmospheric electricity, a conducting rod is used; but it has to be very carefully insulated, so that it may receive all its excitement from the air, and neither give to the earth nor receive any from it. In the Electrical Observatory at Kew, kept under the charge of the British Association, the principal conducting rod is a conical tube of thin copper, sixteen feet high, and projecting from the cupola of the building. It rests below, within the cupola, on a very strong hollow glass pillar, which is the means of insulating it; and the insulation is very much increased by a lamp, which heats the inside of the glass, in the manner already shown in the electrical machine. There is a certain temperature which renders glass almost a perfect insulator; and although this tem-

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When is the greatest danger incurred from lightning? 109. Why is a tree a dangerous shelter? 110. What is used in making observations? How must it be placed? Describe the rod used at Kew.

perature cannot be given to the whole of the pillar, yet if the lower end is heated higher and the upper end lower, there will be some intermediate portion which will have the exact degree for insulation; and this portion will resist the passage of the electricity as well as if the same degree were maintained through the whole length. A pair of fine platinum wires are soldered to the upper end of the conducting rod; and to increase still farther its attraction for the electricity of the air, a lamp is also suspended at the top, and kept burning. It is found that flame has the power of rapidly receiving or dispersing electricity. The apparatus for lowering and raising the lamp is a silk cord running up the hollow of the rod, and attached to it alone. The lower end of the rod branches out into four brass arms in connection with electrometers, which constantly exhibit the strength of its charge, and show whether it is positive or negative.

111. The aurora borcalis has been supposed to be a case of faint lightning discharged far in the upper air, where the rarity is so great that it may flash over great spaces, as we see in an exhausted receiver. But the coincidence between the aurora and distractions of the magnetic needle, render it likely that it is some manifestation of magnetic, rather than thunder and lightning, storms; which is confirmed by the north and south direction of the streamers. This, however, and indeed the whole subject of atmospheric electricity, is as yet very imperfectly understood.

SOURCES OF ELECTRICITY.

112. Hitherto we have regarded friction as the source of electrical excitement; but there are many other ways of evolving it. In general, all disturbances of the molecular state of bodies, whether mechanical or chemical, are liable to produce electricity. All the sources of heat (as well as heat itself) are sources of electricity. We shall now enumerate the various sources in detail :—

Why is the glass pillar heated? How is the attraction of the rod increased? The strength of the charge shown? 111. How has the aurora borealis been explained? What is more probable?

1*st*, *Cleavage* and breakage of bodies is a source of electricity. If a plate of mica is rapidly cleaved in the dark, there is perceived a feeble phosphorescent flame, and we find that the two faces have become charged with opposite electricities. From this it appears that crystals have a permanent polarity in their particles, which is converted into free electricity when they are separated. In the same way, if we break a roll of sulphur, or pound it to pieces, it will be seen to be electric.

113. When two substances have been adhering together by a firm cohesion, if they are suddenly broken asunder they show electricity on the separated faces. If we pour melted sulphur into a wine glass, and, while soft, stick into it a glass tube to be a handle to the mass, and leave it to cool and harden, it will have contracted an adhesion for the glass. If it is now abruptly drawn out, so as to break this adhesion, it will be seen that the two surfaces are electrified.

2*d*, *Pressure.*—If we take the plates of mica, or other crystal formed by cleavage, and press them together, and suddenly withdraw them, we find they have acquired electricity. But the effects of pressure, as of friction, are greatest with unlike surfaces. Let a disk of wood be covered with silk, and the silk coated with resin, and take a disk of metal, and press the two quickly together without friction; the surfaces, on being separated, will be excited; the metallic disk will be negative, the resined silk will have taken a positive excitement, contrary to the character of resinous bodies under friction. It was observed by Haüy that a crystal of Iceland spar, and a few other minerals, became electric by pressing it with the fingers: but the property is shown to be perfectly general; both good and bad conductors give signs of electricity under pressure. In making the experiments, the substances used are cut into very thin circular slices, and each is laid upon a disk with an insulating handle; they are then pressed together by

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112. What is the first mentioned source of electricity? What results on cleaning mica? 113 If two bodies adhere, how may electricity be produced? Show how electricity is obtained by pressure?

holding a handle in each hand. A disk of cork, for example, pressed against another of caoutchouc, causes the first to have positive, the latter negative electricity. Crystallised minerals of a transparent character, such as sulphate of lime, are positive when pressed by cork. Slices of fruit, such as an orange, are negative to cork. If one of the substances pressed is a good conductor—a metal, for example—and the other an elastic substance, as a slice of pith, no effect will be produced; the electricity evolved is combined or discharged before the two surfaces can be separated. That this discharge is the cause of the nullity of effect, can be seen by making the separation slowly in the case of cork and orange; for when the charge of the two surfaces is tested by the torsion electrometer, it is found much feebler than when the operation is quickly performed.

114. The two surfaces must have a difference of character of some kind or other in order to become excited by pressure. If we take a well-dried cork, and cut it across the middle, and press the two pieces together by the insulating apparatus, we may in some instances find an entire absence of excitement. But if one is heated, or receives a higher temperature than the other, a charge will be communicated when they are pressed together; the colder being positive, and the warmer negative. If the one surface be rough, and the other smooth, this difference will suffice to develop electricity, although both should be of the same material and of the same temperature; in this case the smooth surface will be positive, like the cold surface, and the rough surface negative.

3*d*, *Friction.*—This is the source commonly used in the electrical experiments. But in these we confine ourselves to the friction of a very few substances; as the rubbing of sealing-wax and glass rods with cloth, and the action of the glass cylinder of the machine upon a mercurial solution of zinc and tin. In order to investigate and explain the cause of the excitement of electricity by friction, it is

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When is cork affected positively, and when negatively? When will no effect be produced? 114. What is necessary in the two surfaces that they be electrified by pressure? On what is friction most used?

necessary to go over a wide range of materials, and determine the precise effects of each pair when rubbed together. It is found that, except where the two faces rubbed are perfectly identical in character, electricity is always evolved by friction. In good conductors, it is necessary to insulate well the pieces rubbed, to keep the excitement from being carried off and lost. With this precaution, all the metals may be made electrical by rubbing them either on one another, or on non-metallic bodies. When disks of different metals are taken, it is found that there is a certain fixed order that determines which becomes positive and which negative. Thus, in the following series, each metal is negative when rubbed on any one following it, and positive when rubbed on any one preceding it:—bismuth, palladium, platinum, lead, tin, nickel, cobalt, copper, gold, silver, iridium, zinc, iron, cadmium, arsenic, antimony. Supposing we were to take a surface of platinum and a surface of iron, the platinum would be negative, and the iron positive; and so on with any other pair we choose to select. To produce the strongest possible indications of excitement, it is necessary to rub quickly with large sweeps, that the parts exciting one another may be separated as soon as possible; the farther the separation, the less the disposition of the two excitements to join again at the place of contact. When the agitation of the surfaces is produced by throwing the powdered particles of a metal on a plate of the same, the effect is like that of pressing or rubbing an unpolished on a polished surface—the powder is positive, and the plate negative.

115. In general, when bodies are rubbed on one another, the one which suffers the greatest agitation of its particles is negative; so that roughness, high temperature, and extent of rubbing, all increase the negative tendency. If two white silk ribbons, taken off the same piece, are rubbed across one another, the one that is moved in its whole length across the breadth of the other will be positive; and

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When will friction not produce electricity? What kind is evolved, and in what order on the substances mentioned? How should bodies be rubbed together?

the other, which has experienced the most intense action, will be negative. The heat evolved will also be greater in the one rubbed across, and this will add to its negative character. If a white ribbon is rubbed on a black, and if the friction is equal on both, the first will be positive and the second negative, showing that the black dye causes the particles to experience more agitation, or else become hotter than in the white ribbon.

116. The tension of the electricity increases with the pressure and the rapidity of the motion. But there is a limit to the tension which can be produced in any machine; for the tendency of the opposite electricities to come together, and make a discharge at the place of their origin, increases as the tension increases, and at last becomes as great as the power employed to separate them.

4th. Change of temperature.—It has been observed that the tourmaline showed electrical excitement while in the act of heating or cooling, whereas it is perfectly free from electricity while remaining at the same temperature. It always possesses two poles opposite in their excitement; by heating, these display a certain polarity, which in cooling is reversed. The development of the electricity seems to result more immediately from the expansion and contraction caused by change of temperature. The topaz, boracite, and several other minerals, have the same property.

117. The production of electricity by heat constitutes a separate branch of the subject; namely, Thermo-Electricity. Chemical actions are also sources of electricity, but the consideration of these belongs more to Current Electricity than to the present head. The sources above given are such as yield the intense and Stationary excitement whose characteristics we have hitherto been engaged in describing.

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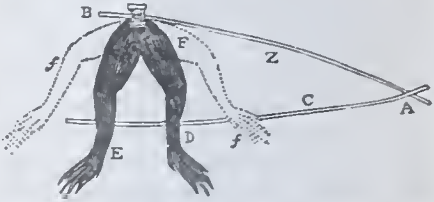
115 When bodies are rubbed together, which becomes negative? Illustrate this by the case of the ribbons. 116. When does the tension of electricity increase? Why is it limited? What is tourmaline? What is observed of it? 117. By what further may electricity be produced?

VOLTAIC ELECTRICITY.

118. Galvanism was the name first given to electricity produced in constant currents, feeble in intensity, and great in quantity; but it is now agreed that the discoveries of Volta (and not of Galvani) were what really constituted the foundation of this science; it is therefore entitled Voltaism or Voltaic Electricity.

FIG. 20.



119. The original experiment of Galvani that excited attention upon this subject, consisted in convulsing the legs of a frog, by making a circle with two metals, and the leg between them. Thus, in the figure, EFD are the legs of a frog, Z is a rod of zinc connected with the nerve which ramifies in the legs, and C a rod of copper touching the rod of zinc at one end and the muscles of the two legs at the other. The circle is thus composed of four parts—zinc, copper, muscle, nerve. When the circle is completed by bringing the two rods into contact at A, after their other ends have been properly connected with the limbs, a convulsion takes place; the sudden contraction of the muscles throws the legs out into the position *f f*. But the very same effect is produced by a discharge of common electricity passed through the nerves and muscles of a limb: hence Volta declared that, in the case of the two rods, a current of electricity was generated; and he inferred from the circumstance that the contact of dissimilar metals was a source of electricity; and, working on this idea, he originated the voltaic pile, which is a series of pairs of plates of dissimilar metals, with a moist substance between each pair. He asserted, further, that the bare contact of the metals is the exciting cause of the electricity: but this has

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118. What is galvanism? By what name is it here called? 119. Explain the experiment of Galvani. What inference was drawn by Volta? What is the voltaic pile?

been disputed and denied; and it is maintained in opposition, that a chemical action of some sort is the origin of the electric current. The latter supposition, if it does not explain everything, is at least the most tenable of the two; and we shall therefore commence by enumerating the various chemical actions which lead to the production of currents.

120. If we plunge into nitric acid, one after the other, the ends of the two wires connected with a voltaic electrometer, (to be afterwards described,) electrical excitement is made apparent. The wire first immersed is seen to have positive electricity, and the other negative. If both were immersed at the same instant, probably no electrical action would arise; but the successive plunging causes the first to be oxidised, while the other is as yet untouched, and the difference of the acid's action on the more and less oxidised wires suffices to give birth to an electric current. This may serve as an example of the circumstances that determine whether a chemical action shall evolve electricity or not; it coincides, moreover, with what has already been stated as to the necessity of some inequality in the kind of materials used in order to bring forth an excitement.

121. When an acid combines with an alkali, the acid acquires positive and the alkali negative electricity. Thus if a platinum capsule, containing a solution of caustic potash, is put in connection with one wire of the electrometer, and if a piece of platinum, connected with the other wire, is moistened with nitric acid, and plunged into the potash, there appears instantly the indication of a current, such as to show that the capsule with the alkali is negative, and the slip of platinum with the acid positive. Thus one of the most common of chemical actions is a distinct source of electricity.

122. But solution, apart from chemical combination, is a source of electricity. If nitric acid is brought into contact with the muriatic (or hydrochloric) acid, there is no chemical combination in the highest sense, there is merely

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120. How must wires be plunged in nitric acid to produce electricity? 121. When acid is combined with alkali, what results? 122. Give examples to show how solution produces electricity.

solution (as when alcohol is mixed with water); yet a current arises, and the nitric acid is positive and the other negative. Phosphoric acid is positive to all the other acids, as well as to alkaline solutions. When acids are dissolved in water, they are positive and the water negative; when alkalies are dissolved in water, they are negative and the water positive: so that water is like an alkali to acids, and like an acid to alkalies. The apparatus for developing the current in these cases is the capsule and platina-slip already mentioned: the capsule contains the water, and is connected with one pole of the voltaic electrometer; the acid or alkali, if solid, is held by a platinum pincers connected with the other pole, which is plunged into the water. If the acid and alkali are liquid, a piece of spongy platinum is used, and dipped in the liquid, and then plunged into the water.

123. The case of what is called double decompositions of neutral salts, where two salts decompose one another, and exchange acids and alkalies, making two new salts, is remarkable for giving rise to no current of electricity, provided the quantities are exactly proportional, so as to leave no excess of any element. There can be no doubt that electricity arises in some of the stages of the operation of decomposing and combining, since either of these actions separately always yields excitement; it must therefore happen that the electricities evolved exactly neutralise each other.

124. Since simple solution, as well as chemical unions, gives rise to electricity, it is necessary to discriminate in individual cases which of the two has actually produced a given current. This discrimination can be made, on the ground that a chemical union always evolves heat, and raises the temperature of the mass; whereas dissolutions generally cause cold, and lower the temperature. A delicate thermometer may therefore indicate which of the two actions has happened.

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123. When, in the case of decomposition of salts, is electricity not evolved? 124. How can it be known from what the electricity proceeds?

125. In the action of acids and alkalies upon metals, there is apt to be a complication of effects. The simple action of an acid upon a metal is like that of an acid on an alkali; the acid is positive, the metal negative. But when an acid dissolves a metal, there is always the additional effect of the action of the newly-formed substance upon the liquid which the metal is immersed in; this may be of the same character as the action on the metal, and may therefore strengthen the resulting current, or it may be opposite, and weaken it. When there are two metals employed in one circuit, if both are acted on, their effects will contradict each other; and the result will be only the difference of the actions: hence in the voltaic circuit, which commonly consists of two metals and a liquid between them, it is requisite, in order to produce the highest effects, that the one should be acted on and the other not. And in general, the great art in combining several chemical actions to evolve electricity, is to make all the excitements that occur agree with, and not oppose, each other.

126. If two different metals are plunged into the same liquid, the one will probably be more attacked than the other; hence the one most attacked will be negative, and the liquid positive, which will render the other metal positive likewise, in spite of its own tendency to become negative. Now, as the metals differ very much in the quality of being acted on by acids—some, such as zinc, tin, and lead, being very rapidly and powerfully combined, and others, like platinum, gold, and silver, resist chemical action—it is desirable to choose two metals from the opposite extremes. Thus zinc is chosen for the negative metal, and platinum for the positive, in order to yield the greatest amount of action. Copper, although far inferior in resisting power to the precious metals, is yet greatly superior to zinc, and its cheapness causes it to be much used for the positive element of circuits. Thus, in the figure, let *z*

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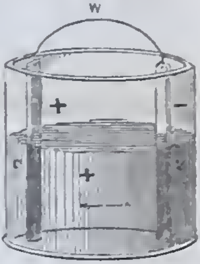
125. What is the action of acid on a metal like? Of what does the voltaic current consist? When will it produce the highest effects? 126. Of two metals in a liquid, which will be negative? Which metals are most acted on by acids? Which least?

FIG. 21.



represent a plate of zinc immersed in a liquor capable of acting on it, and *c* a plate of copper; the liquid will combine with the zinc, and give it a negative electricity, and be itself positive; the copper will also be acted on, but more feebly: and hence, instead of being negative, it will receive a positive excitement from the intervening liquid, and act as a conductor to carry round the positive current. When the plates have no connection outside of the liquid, each is attacked according to the degree that it yields to the agency of the liquid; but when the circle is completed by the wire *w* joining the unimmersed ends of the plates, the zinc is more attacked than before, and the copper less attacked. The carrying round of the electric currents causes this effect.

VOLTAIC CIRCLES AND BATTERIES.

127. If a disk of copper and one of zinc are taken, and a wet cloth put between them, electricity will be produced —the zinc will be negative and the copper positive: if a wire is brought from the zinc to the copper, an electrical *current* will be established; the positive electricity flowing from the zinc through the moist cloth to the copper, and along the wire to the zinc again; and negative electricity flowing in the opposite way, or from the zinc round the wire to the copper, and from the copper through the cloth to the zinc. The apparatus is in principle the same as that figured in the preceding article. Such a combination of zinc, wetted cloth, and copper, makes a couple, or single circle of Volta. The cloth is moistened with water containing a small quantity of acid or salt.

128. The pile of Volta is an aggregation of these simple circles, so ordered that the same currents flow in the same direction in them all. Thus to build up the pile, let an

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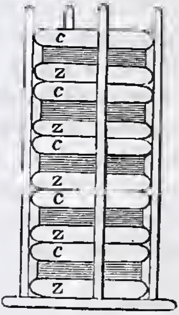
Describe the figure. What is the effect of joining the metals? 127. If copper and zinc are separatod by a moist cloth, how will the current flow? With what is the cloth moistened?

upright stand be formed with glass or wooden rods ending in a bottom: place on the bottom a disk of zinc *z*, then a wet cloth, then a disk of copper *c*; upon the copper lay a another series of zinc, cloth, and copper, and so on for any number, the pile terminating in a disk of copper above, as in a disk of zinc below. The zinc end will be negative, and the copper end positive; and if a wire is passed from the zinc to the copper, the circle is said to be closed. Its action then rises to the highest pitch, and currents of the two electricities circulate around. The lowest zinc, itself negative, renders the moist cloth above it positive, which transmits a positive current to the copper; the copper passes this to the next zinc, which transmits it by conduction, along with what itself generates, to the second cloth; the double force is passed to the second copper, and by it to the third zinc, which the copper touches; the third zinc communicates it to the third cloth, increased by its own action on the moisture of the cloth, and thus a threefold charge is carried to the third copper, and so on. On the other hand, a negative current of equal strength circulates downwards, augmented at each step in the same manner; for the lowest zinc plate, while originating a positive charge proceeding to the copper above it, sends a negative charge the other way; that is, by the conducting wire that goes from it to the uppermost copper, which transmits it through the wet cloth to the uppermost zinc, where another of the same is produced and sent downwards. Thus a double negative charge is passing down through the cloth second from the top to the second zinc, there to be reinforced, and sent to the third, and so on. The surface of contact of a plate of zinc and a film of liquid, is always understood to be producing the two electricities, and sending one off in one direction, and the other

FIG. 22.



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128. Describe the pile of Volta. How is the positive current transmitted? In what direction the negative? How does this resemble the action of the electric machine?

in the opposite ; just as at the contact of the cylinder and cushion in the electrical machine.

129. By such a pile the various electrical effects can be visibly produced. When the wires attached to the two ends are brought together, a spark may be seen. A shock is felt by passing the current through the body, which is done by holding a wire in each hand. Heat is also produced at the ends of the wires where they touch. But to make the effects decided, a very large pile must be formed, extending perhaps to a hundred pairs or circles, each disk being the size of a crown-piece.

130. The peculiarity of the excitement of the voltaic pile, and of voltaic currents generally, is their feeble intensity. This is the point of contrast between Voltaic and Tension Electricity. When a metallic surface, such as the coating of a Leyden jar, is electrified by the machine, the separation of the two kinds is carried very high, so that their tendency to come together is intense and violent. The standing accumulation at the two ends of a single polarised particle is greater in machine-electricity than in any other kind. If we take a particle of copper in the plate of a voltaic circuit, and a particle of tinfoil in the coating of a Leyden jar, the second is immensely more charged than the first. The distinguishing character of the voltaic electricity is *quantity*. A large amount of excitement of a feeble kind is generated, and passed round the circle. Instead of highly charging the superficial particles of a metallic surface, it charges the entire solid mass with a low intensity, perpetually renewed as it is taken off: If the current is resisted by insulation, the action does not go on heightening the tension of the charge, but stops altogether. When this difference in the mechanical character of the electricities of friction and contact is allowed for, they can be proved to be identical in their nature and effects.

131. The intensity of voltaic electricity is greatest when

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129. How are the electric properties of the pile made evident? What must be the size of the pile? 130. Explain how voltaic and tension electricity differ. Are they still identical?

the pile is made up of a very great number of small plates. Supposing an equal amount of surface of copper and zinc employed, the shock, and other indications of a strong charge, would be greater if it were cut up into many small circles, than if it formed a few large ones. But the actual quantity of the excitement would be greatest with the large plates. We shall afterwards see that chemical and magnetic effects are the measures of quantity independently of intensity. The two qualities may be compared to heat of different temperatures. A tubful of water at 100 degrees has a greater quantity of heat than a cupful at 200 degrees ; but the latter is the more intense of the two. The cause of the greater intensity in the long pile of many plates, is the resistance offered by the length of bad conductors through which it passes ; but from the intrinsic feebleness of the exciting action, this resistance diminishes the quantity that could be evolved. The presence of the excitement already produced is always a bar to the evolution of new excitement. If the exciting force be of a certain power, it will go on raising the tension till the latter has become so strong as to equal the force ; at this point the action must cease, or the opposed electricities will be combined as fast as they are formed, if they are formed at all.

132. As the pieces of cloth between the zinc and copper of Volta's circles are of no use but to contain the acting substance, they may be dispensed with, and the plates inserted in a vessel containing the proper kind of liquid. Volta, accordingly, made an arrangement that he called the " couronne des tasses" (the crown of cups) ; which consists of a row of cups or jars filled with acidulated water, and each containing a couple of plates. Thus let A, B, D, E, be four jars half-filled with liquid. Into the first is placed a zinc plate Z, and a copper plate C ; if these were connected, a current would arise, as was formerly

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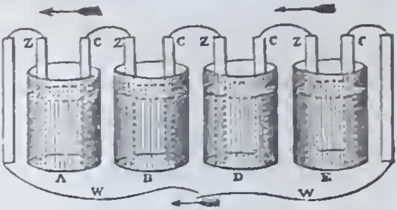
131. When is the intensity of voltaic electricity greatest ? Illustrate the difference between intensity and quantity. What causes greater intensity in the long pile ? 132. What is the use of the cloth between the metals ? How may it be dispensed with ?

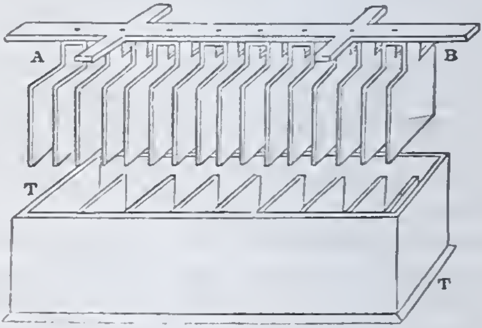
FIG. 23.



described. But instead of connecting these, let a wire pass from C to Z, a zinc plate in the second jar, which contains also a plate of copper connected with the zinc of the third jar; and in like manner the copper of the third is connected with the zinc of the fourth; the copper of the fourth would connect with the zinc of a fifth; and so on. Let a wire W proceed from the copper at one end, and come into contact with a wire from the zinc at the other; the circle is closed, and the action circulates. From Z to C in the first jar A, there passes through the liquid a positive current, which is carried by the conducting wire to the second Z, and at Z's contact with the liquid joins a second charge, and both pass on to C, exactly as we described in the pile. In the opposite direction a negative current will proceed, reinforced, like the other, at every plate of zinc.

133. A more compact apparatus on the same principle is that called the Trough Battery. A trough of porcelain TT is divided by partitions into separate compartments or

FIG. 24.

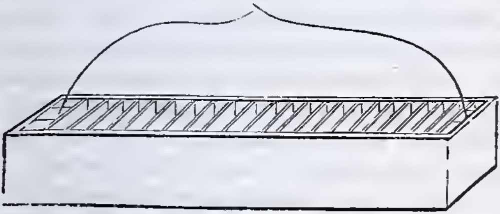


Describe the "couronne des tasses." How are the metals united? How do the currents circulate? With what effects? 133. Describe the Trough Battery.

cells, each cell being intended to answer the purpose of one of the jars, or contain a pair of plates. The plates are suspended in a piece of wood A B, at the proper distances, and connected with one another by metallic slips. The battery of the Royal Institution, made under the direction of Sir Humphry Davy, and used by him for his celebrated discoveries of the compound nature of the alkalies and earths, was of this form; it consisted of 2000 double plates, and its acting surface amounted to 128,000 square inches.

134. Another kind of trough is formed by making the partitions themselves the acting plates. A plate of copper and a plate of zinc are soldered together, and each compound plate makes a partition wall, the liquor being contained between them.

FIG. 25.



135. Dr. Wollaston effected an improvement on the galvanic trough battery by making the copper plates double, so that each enclosed a zinc plate, and faced it on both its sides. The action on the zinc is very much increased by thus enlarging the copper; for it is found that the energy of the circle depends not only on the metal attacked, but on the conducting metal. The greater the conducting surface, and the nearer it is to the zinc, the more intense and rapid is the combination of the liquid with the zinc. In the circles made up of a single plate of zinc and a single plate of copper, the zinc is acted on only on the side facing the copper; but by Wollaston's arrangement, both sides are made to produce currents. The case is exactly analogous to single-surface electricity, where the charge taken

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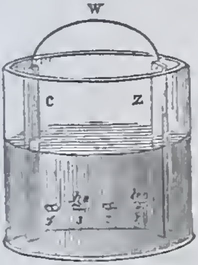
Of how many plates did Davy's battery consist? Of what surface? 134. How is another kind of trough made? 135. In a battery, which is the metal attached? What was effected by Wollaston's arrangement?

in is entirely dependent on the capacity of surrounding surfaces to receive an opposite charge by induction. In so far as zinc is acted on by mere ordinary chemical action, the size and distance of the copper plates are of no moment; but the increase of action arising from the current in a closed circle, is in proportion to the quality and size of the metallic plate that serves as the conductor.

136. All the batteries above described have one especial imperfection among many others; which is, that from the moment they are set in action, their strength constantly decreases. At the end of an hour, or two hours, their power is almost reduced to nothing. This is owing to the reaction on the plates of the products of the chemical combinations. It is therefore a great object to construct *constant batteries* (as well as to arrange the elements so as to prevent the rise of conflicting currents) and otherwise to heighten and economise the force of the battery. But the nature of the schemes which have been adopted for these ends cannot be understood without attending more closely than we have yet done to what goes on in the voltaic circuit.

137. Let us consider again a single copper and zinc pair immersed in a liquid; and let the liquid in the first place be pure water. Let z and c be the two plates, and suppose a row of water particles to lie between them. Each water particle is a compound of a particle of oxygen and a particle of hydrogen; and it is almost certain that the following process is gone through when the conducting wire w arches the two plates, and closes the circuit. A particle of water (1) is attracted to the zinc by its oxygen constituent; the affinity of the zinc for oxygen surpasses the affinity of hydrogen for oxygen, and the effect of this is to decompose the particle, and form a particle of oxide of zinc,

FIG. 26.



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136. What is the imperfection of the batteries above described? To what is this owing? What is desirable? 137. Of what is water composed? For which has zinc an affinity? What does this cause?

and leave a particle of hydrogen, producing at the same time a certain amount of free electricity; the oxide of zinc having a negative charge, and the hydrogen a positive charge. The negative charge of the oxide of zinc passes on through the metal plate *z*, the positively charged hydrogen is attracted to the oxygen of the next particle of water, and its electric state adds to its natural attraction for this atom of oxygen, and accordingly it overpowers the existing attraction that keeps the two elements together, combines with the oxygen, and sets free the hydrogen of No. 2. But this decomposition evolves a new charge of electricity, the water particle being positive and the hydrogen negative. A third particle of water is decomposed in the same way, and a fourth; and so on till the plate of copper is reached. The last particle of freed hydrogen encountering it can decompose no further; it communicates its excitement by contact to *c*, and rises up to the surface, and is dissipated in the air; so that the conduction through the water is effected only through a series of decompositions and combinations, showing the mode whereby liquid particles receive and transmit polarity. The influence evolved at the zinc is necessarily weakened by having to operate so many actions; and it is found that the greater the distance between the two plates, the weaker the current is. Even if nothing were absolutely lost at the transmigration of each water particle, there would be a delay, from time being necessary to all motions, even the quickest; and delay would be resistance.

138. It is found that a circle charged with pure water, such as the above, is very weak, and soon ceases; but if a small quantity of sulphuric acid is added, its energy is renewed and quickened. The oxide of zinc formed on the plate stands between the water and the pure metal, and the action is thereby arrested; but the sulphuric acid combines with and dissolves this oxide, and exposes a clean surface for the further action of the water. But the com-

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Explain the operation of passing from the zinc to the copper. What tends to weaken the current? 138. By what may the action of water be strengthened? How does this operate?

bination of the sulphuric acid with the oxide of zinc is itself a source of electricity of the same kind as the water action—that is, it makes the zinc negative and the liquid positive; this is, therefore, an addition to the force. But an unfortunate drawback belongs to the acid action. The dissolved sulphate, by being made positive, has an attraction for the copper plate; for this plate, while receiving a positive excitement from the zinc through the liquid, is returning or radiating forth a negative current through the zinc, thus presenting an attraction for all positive elements as well as for the hydrogen. The sulphate of zinc is therefore drawn towards it; and as it cannot go off in air bubbles like the hydrogen particles, it sticks and deposits a coating on the plate, which mars its conducting power; so that what was good in the beginning is in the end an evil.

139. Another source of weakness occurs in the contact of the hydrogen with the copper. The attraction of these two elements is essential to the maintenance of the current; but the same attraction that brings the hydrogen close keeps it there, and constitutes a resistance to the succeeding portions. It would be well that the hydrogen could be got rid of the moment it touches the copper, instead of adhering and stagnating, and occupying the ground which other particles are pressing forward to seize. Now it is found that the addition of nitric acid to the sulphuric acid and water, serves to absorb the free hydrogen, and in this way proves an accession to the strength of the current. But the addition of any new ingredient leads to a new series of actions, both from its chemical agency and from its contact with the other elements of the solution; these new actions being sometimes with and sometimes against the general current. By using sulphate of copper alone, in addition to the water, the hydrogen may be absorbed; the sulphate will be turned into sulphuric acid, and copper, which the hydrogen displaces, deposited on the copper plate, thus

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What adds to the force? What detracts from it? 139. By what is the hydrogen attracted? What results from this? In what ways is it corrected?

maintaining a clean and ever-renewed copper surface. The hydrogen, when not absorbed in such a way as this, is very apt to act upon the compound of zinc dissolved in the liquid, and reduce it upon the copper plate, making a second zinc surface, whereby the action must soon come to a stand altogether; for two identical plates can yield no excitement.

140. In the forming of constant batteries there are two improvements which have been of especial value. The first is the amalgamation of the zinc, or the coating of it with mercury, thereby presenting a combination of zinc and mercury instead of pure zinc. This is found to diminish to an extraordinary degree the waste of the zinc, or to produce an equal amount of electricity by a much smaller consumption of the acting metal. It is not well understood in what way the mercury contributes to this effect. We have a parallel to it in the rubber of the electrical machine, which is an amalgam of zinc and tin, and far surpasses in effect any other material that could be used; but in neither case is it clearly known what action goes on. The only supposition that has been made as to the way in which the mercury saves the zinc in the voltaic circle, is that it takes away local currents—that is, the naked zinc plate is conceived to produce currents which come round to itself instead of proceeding to the copper, and thus detract from and contradict the general effect.

141. The second great improvement in batteries is the use of *diaphragms*, or porous and permeable partitions between the zinc and copper. These are intended to prevent the dissolved zinc from passing to the copper plate, to be precipitated or reduced there. The partition must, however, allow a free contact of the liquids on each side of it, otherwise it would arrest the action altogether. Many kinds of material have been tried as diaphragms, it being somewhat difficult to find a substance which will allow the liquids on each side to be in contact within its pores, and

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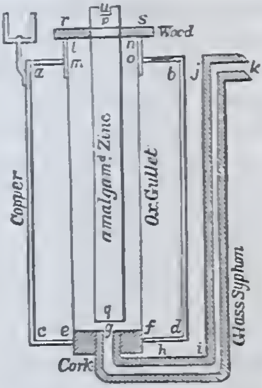
140. What is the amalgamation of zinc? What effects does it produce? What is supposed to be the cause? 141. What are diaphrams? For what are they used?

at the same time keep the one from passing through to mix with the other; besides having other virtues, such as not to become closed up by the precipitation of the salts, not to contain bad conducting material, and not to produce currents from the action on their own ingredients. Bladder, tanned leather, pasteboard, cloth, thin slices of wood, clay, porcelain, &c., have been used, and each has its disadvantages.

142. The *Constant Battery*, introduced by Professor *Daniell*, is constituted as follows:—Each cell or separate circle is of the form of a cylinder, whose construction will be understood by the figure, which is a section down the middle: *a b c d* is the outer cylinder made of copper; it is open at the top, but closed at the bottom, except that there is an aperture *e f*, which receives a cork containing the end *g* of a glass syphon tube *g h i j k*. On the top *a b*, a copper collar *l m o n* rests upon two horizontal arms *a m*, *b o*. Between this collar and the cork neck at the bottom, a cylindrical diaphragm is stretched, made of ox-gullet, and forming an internal cavity connected at the bottom with the syphon outside. In this cavity there is placed a rod of amalgamated zinc *p q*, suspended from *r s*, a piece of wood lying over the rim of the diaphragm. Into the same inner cavity of the diaphragm is poured acidulated water, which surrounds and acts on the zinc; around the diaphragm, in the outer cavity, there is contained a solution of sulphate of copper. The action of the cell is this: the acidulated water acts on the zinc rod, and excites electricity, at the same time dissolving the zinc, and forming a salt of zinc within the diaphragm; this, from its being

FIG. 27.



What objects must they answer? Of what have they been made? 142. Describe the Constant battery. What liquid is poured in it? Where? What action does it produce?

heavier than the other liquid, sinks to the bottom, and passes into the syphon, and is carried off if new liquor be added from above to give a sufficient pressure. In this way the product of the action on the zinc is got quit of. The voltaic current is freely allowed to pass through the membrane to the outer cell, and deposit hydrogen on the copper cylinder; which hydrogen, acting on the sulphate of copper, is absorbed by it, and displaces metallic copper, which is deposited on the cylinder, the sulphate being converted into sulphuric acid. A coating of its own substance is thus continually forming upon the copper cylinder, keeping it always fresh and new. To renew the waste of the sulphate of copper, a few solid crystals are suspended in connection with the liquor of the outer cell, which are dissolved as they are required. A battery formed of such cells is found to maintain its strength without diminution for many hours; it also prevents many of the sources of waste of power that were present in former batteries. The power of the battery is found to increase with the temperature; but to work it at a high heat, a porcelain diaphragm must be substituted for the ox-gullet. In subsequent batteries the syphon was disused.

143. A rod of zinc, in a cylinder of copper, is the best form for producing the greatest possible action on the zinc; the latter is confronted all round with a surface of copper, and is therefore acted on equally on every side. A rod and cylinder could be surpassed only by a ball in a hollow sphere, which would not be so convenient.

144. Batteries have been formed by circles where the copper and zinc were rolled up in a spiral, thus affording a large surface in a small solid bulk. It has already been mentioned, that in order to get the electricity in greatest possible quantity, circles of large surface are chosen.

145. *Grove's Battery* is of the same general construction as Daniell's; but instead of copper, platinum is employed, which, being of all metals the least oxidisable,

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How is the salt of zinc disposed of? What effects does the hydrogen produce? 143. What is the best form for acting on zinc? 144. What is the advantage of batteries in a spiral form?

makes the best conducting plate for a circle. Zinc and platinum form the most powerful couple that can be used. Accordingly, Grove makes the outer cylinder of the circle of platinum, and the diaphragm or intermediate cylinder of porcelain, which contains the amalgamated zinc rod. The outer cavity between the platinum and porcelain cylinder is filled with nitric acid, and the inner cavity around the zinc with dilute sulphuric acid. A very powerful current is generated by this arrangement; and although of an expensive construction, from the employment of platinum, it has come into general use. The action is of the same nature as in Daniell's circle. The zinc is oxidised and the oxide dissolved in the sulphuric acid; sulphate of zinc being thrown down, but confined by the partition within the inner circle. The positive current passes from the inner to the outer liquid, and hydrogen is evolved at the platinum, and taken up by the nitric acid. There is no metallic deposit of any kind; but both liquids are changed by their actions, and require to be renewed from time to time.

146. The principles which determine the quantity of electricity evolved in a circle or battery have been reduced to precise mathematical theorems by Professor Ohm. The following are the general statements on which the theorems are founded :—

1*st*, The quantity of the current depends on the tension or strength of the electricity, and on the goodness of the conductors, or the absence of resistance to its passage.

2*d*, The strength and quantity of the current depend, in the first place, on the material used in the circle: the greater the affinity of the acting plate for oxygen, and the less the affinity of the conducting plate for oxygen, the greater the action. In the second place, the result increases with the size of the plates, particularly the conducting plate; it is of no use to increase the zinc surface if the copper or platinum surface remain the same.

3*d*, The resistance in the circle is, first, that of the

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145. How does Grove's battery differ from Daniell's? Do they differ in action? 146. On what does the quantity of electricity depend? On what its strength and quantity? What increases the result?

fluid conductors in the cells; and second, that of the solid conductors, or the wires that close the circuit. The smaller these resistances the more powerful the current.

4*th*, The resistance of the fluid is in proportion to the thickness of the layer between the plates. By placing the plates very near, the enclosed liquid is so much thinner, and less resisting.

5*th*, The resistance in passing through the wires is as their length, and as their thinness. The shorter and thicker a wire is the more easily does the current traverse it.

6*th*, The tension or strength of the electricity increases with the number of the plates. If the plates are few and large, the quantity that could be produced is very great; but if there be much resistance, it is completely checked. Hence if the circuit is closed with bad conductors, or if the wires are long and thin, a battery of many plates is necessary; but if the circuit is closed by good conductors, and the resistance in every way small, a few plates will maintain the current, and produce it in considerable quantity.

147. The conducting powers of the metals themselves are very unequal, supposing them made into wires of equal sizes. The following table expresses the comparative powers of several of them :—

Silver,	136	Platinum,	22
Gold,	103	Iron,	17
Copper,	100	Mercury,	2-6
Zinc,	28		

Thus a copper wire of 100 feet offers the same resistance as a silver wire of 136 feet, or an iron wire of 17, all of equal thickness. Hence in considering the resistance offered by the solid parts of the circuit, the material that it is composed of must be attended to.

148. In like manner, there are great differences in the conducting powers of liquids. Distilled water is very weak

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What resists the current? To what is the resistance of the fluid proportional? When are many plates necessary? When but few? 147. Compare the conducting powers of metals. 148. Of liquids and metals.

compared with saline solutions, alkalies, and acids; but the best of liquid conductors are very feeble compared with the metals.

EFFECTS OF VOLTAIC ELECTRICITY.

149. The voltaic current may produce Heat, Light, Chemical Decomposition, and Mechanical Power, as well as actions on the Animal Frame.

150. The production of *heat* takes place when the current is resisted, but not entirely checked. Thus if the circuit be closed by a bad conductor, and the tension high enough nevertheless to force a current through, the resisting portion is intensely heated. It is a general rule, that when electricity is interrupted, it passes into heat. Thus if a powerful pile is closed by a thin wire, the latter is very soon turned red-hot and melted away. If gold leaf is made a part of the circuit, it is quickly heated and volatilised. Platinum, which cannot be melted by the heat of ordinary furnaces, yields to the voltaic pile. Iron and steel wire are melted and burned with the emission of brilliant sparks. Thus electricity is one of the means of producing very high degrees of heat. In this action upon bad conductors we have one of the links which associate electricity and heat: a simple mechanical circumstance suffices to convert the one into the other. The relative conductibilities of metals and other bodies can be experimentally determined by observing their rise of temperature when a current is transmitted: that which becomes hottest is set down as the worst conductor when other circumstances are alike.

151. The fusion of all the metals, as well as of many of their mineral compounds, can be effected by passing powerful currents through them when they are attenuated into leaves or fine wire.

152. *Light* can also be produced by the voltaic circuit, sometimes of very great brilliancy. The circumstance of its appearance is the same as in machine electricity;

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149. What may the voltaic current produce? 150. When is heat excited? How does it act on different metals? 151. How may fusion be effected? 152. When light produced?

namely, a disruptive discharge through a bad conductor. Of course when bodies are highly heated they become luminous, as a mere consequence of the heat. The metals, when made red-hot, or burned by electricity, have exactly the same luminous appearance as they always have when subjected to the same heating action. The instant that a circuit is closed by bringing the wires together, a spark is seen at the joining; and if, after contact, the ends of the wires are kept at a little distance, a constant stream of sparks passes between them. But the greatest brilliancy of light is caused by making the wires end in pieces of charcoal, and bringing the points of the charcoal together. A dazzling spark is now produced; and if the pile be powerful, a brilliant stream may pass from one point to another, while they are held a little way apart. In the course of the action, the charcoal points are worn away; a stream of particles constantly flows from the one to the other; and the light issues from these particles, as the white light of a gas flame comes from the particles of carbon which are thrown out into the flame, and remain there red-hot for an instant before being burned. When sparks are passed between metallic wires or balls, it is found that the surfaces are scathed, as if their outer particles were torn off and sent in a shower through the blank interval between the two. The disruptive discharge is always productive of mechanical violence and heat, both on the surfaces of the conductors and on the substance of the intervening dielectric, and this may be the primary cause of the spark.

153. The *chemical action* of the pile in decomposing compound substances is the most important of all its effects, and is such as to render it a great chemical agency. The electric circuit is a medium whereby the power evolved when two bodies combine can be carried to a distance and made to separate a combination, or reduce a compound to its elements. This power was discovered in the beginning of the present century by Carlisle and Nicholson. The

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When a circuit is joined, what is the effect? When is the light most brilliant? From what are the sparks produced? 153. What is the chemical action of the voltaic pile?

first substance decomposed was water, which had been previously shown to be a compound, by producing it from oxygen and hydrogen burned together. The inverse process of reducing the water to its separate gases had not been effected before. If the two wires of a battery are immersed in water at a little distance from one another, bubbles of gas appear at each. The gases may be collected by glass bells (adapted to the collection of gases) being placed over each wire. The wires are formed of platinum, which has no affinity for either gas; if they were of iron, the oxygen would combine with the point of the wire on which it is evolved, and form an oxide. The quantity evolved will increase as the wires are brought nearer; and it is increased still further by substituting metallic leaves or thin strips for the wires. Oxygen always rises at the positive wire, or the wire from the zinc; and hydrogen at the negative, or the wire coming from the copper or platinum end of the battery. The bulk of the hydrogen produced is twice that of the oxygen, which is in accordance with the proportions which combine together to produce water.

154. The action which takes place in the water by a current of electricity passing through it, is a series of decompositions and combinations exactly like that described as occurring between the copper and zinc in the cell. The positive wire attracts a particle of water by its negative atom, the oxygen, and with a force that overpowers its attraction for the hydrogen atom, which is set free with a high negative charge; by this charge the hydrogen acts on the next oxygen atom, and draws it away from its hydrogen, making a new particle of water. The hydrogen, now set free, goes to a third water particle, and decomposes it; and so on till the other wire is reached, which, being highly positive, the hydrogen ultimately comes upon it, and is carried off, so that although decomposition passes all through, the gases are set free only at the wires. Here, then, we have the

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Describe the process of decomposing water. By which wire does oxygen rise? By which hydrogen? 154. How are the atoms of water decomposed? When are the gases set free?

electricity given forth by the combination of zinc with oxygen in the cell, passed along and expended in overcoming the affinity of the two elements of water for each other. In this case we may say that electricity and chemical affinity are one and the same thing; the electricity is, in fact, nothing else than chemical affinity set free and conducted round a circle in a current, to act as such in another place. The remarkable thing is, that the chemical polarity is transmissible through metallic conductors, as well as through compound substances, where it acts strictly in its own character.

155. When Sir Humphry Davy had constructed the Royal Institution's large battery of 200 plates, he applied it to the decomposition of bodies, and discovered that the alkalies, such as potash and soda, resolved themselves into oxygen and a metal. The earths (lime, for example) were similiarly decomposed. The discoveries of Davy have been extensively followed up, and the conditions of electrical decomposition accurately ascertained. It is not all compounds that can be decomposed by the voltaic battery.

156. The term *electrolysis* is applied to decomposition by electricity; *analysis* being the term used by chemists for ordinary decomposition. Bodies which can be decomposed by the current are called *Electrolytes.*

1*st*, The first principle of electrolysis is, that the compound must be in a *liquid* state. Solids are not decomposable. Ice, for example, resists the most powerful currents. Hence if a solid body is insoluble, it must be melted, and in that state held between the poles of the battery.

2*d*, The second principle is, that the elements always take a definite direction. The oxygen goes uniformly to the positive pole, and hydrogen or a metal to the negative. Upon this tendency substances are classed and set down as positive or negative in character, according to the pole to which they go. Thus oxygen being attracted to the positive pole, is reckoned an electro-negative substance; hydro-

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What is remarkable in the decomposing power of electricity? 155. What discoveries were made by Davy? 156. What is electrolysis? Analysis? What is the first principle of electrolysis? The second?

gen and metals electro-positive. When a salt is decomposed, the acid goes to the positive pole, the base to the negative. If sulphate of copper, for example, were taken, sulphuric acid would appear at the positive pole, proving itself to be electro-negative like oxygen.

3*d*, In the third place, the chemical actions are equal to one another; the combination which originates the electricity is exactly equal to the decomposition that it can cause. A certain amount of zinc, oxidised and dissolved, will yield an equivalent amount of decomposing force; or should, if the conduction were perfect, decompose exactly the same quantity of oxide of zinc. When substances are combined together in chemical union, there is generally an evolution of heat or electricity, as if less of these was required in the compound than is contained in the substances in their separate state. Accordingly, when a compound is decomposed, whatever was given out at the time of its formation is taken back again; so that while combinations give forth certain influences, decomposition absorbs these. And in the voltaic circuit, it is found that the decomposition between the wires is exactly measured by the amount of material consumed in the cells, according to the scale of atomic proportions. It is precisely analogous to the case of what is termed *the double decomposition of salts.*

4*th*, None but simple compounds can be decomposed. Complex compounds, such as sulphuric acid, nitric acid, peroxides, and perchlorides, are not decomposable by the current. Protoxides and protochlorides, or the combinations of metals with the lowest proportion of oxygen and chlorine, represent the decomposable substances. Chlorine, like oxygen, is an electro-negative element: when it has been combined with hydrogen (hydrochloric acid) or with a metal, it is evolved at the positive wire of the circuit. The elements of hydrochloric acid are sometimes used to designate the two constituents of an electrolyte; the atoms that pass to the positive pole are called the *chlorous* mole-

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How do the chemical actions compare? When is electricity evolved? What principle of composition and decomposition is stated? What compounds can be decomposed? Mention some that cannot be?

cules; the others, which pass to the negative pole, are called the *hydrous* molecules.

5*th*, The affinities of the most opposite substances are the most liable to be overcome by the electrical current. Thus oxygen and the metals are reckoned intensely opposite in their character, and by virtue of this opposition, their chemical affinity (which is regulated on the principles of polarity, where opposites attract) is intense; and the action of electricity in counteracting this affinity is also decided. Chloride of sulphur, which is a compound of elements not much opposed to each other, is not decomposed by electricity.

157. The *shock* of the voltaic pile differs from the discharge of a Leyden jar; the electricity of the pile being of feeble intensity, it does not give the blow received from the jar. The greatest shock is derived from the pile of many plates. If, after moistening the hands in salt water, to heighten the conducting power of the skin, we grasp the two wires, one in each hand, a shock is felt at the first contact, and then a heating current up the arms, and a tingling sensation in the hands. A shock is also felt at the separation, arising from the sudden return of the polarised fibres of the arms to their natural state If the tongue is placed between two wires, or between a piece of zinc and a piece of silver which touch one another, a bitter taste is felt. When a current passes in any way through the eyes, a flash of light is seen. When strong voltaic batteries are discharged through the bodies of animals recently dead, their limbs and features are convulsed and made alive in a hideous way. Experiments have been made on executed criminals, which showed that electricity could in some degree act the part of the nervous currents in moving the bodily organs. By stimulating the nerves of the lungs, a laborious breathing was recommenced; by passing currents through the nerves of the face, the features moved and stretched themselves out into horrible grimaces;

Which substances are most easily decomposed by electricity? 157. If the wires of a pile are grasped, what results? How may the taste be affected? The eyes? What are the effects on dead animals?

when one wire was connected with the hip and another with the heel, the leg, if bent, threw itself out with great force. In the same way the fist could be closed or the hand opened by touching the proper nerves with one wire and the points of the fingers with the other. These results are only extensions of the original experiments of Galvani.

APPLICATIONS OF THE VOLTAIC CURRENT.

158. The first practical application of voltaic electricity to the arts, was the protection of the copper bottoms of ships from the destructive action of the sea water. Sir Humphry Davy suggested that nails or wires of zinc should be fastened at intervals on the copper plates, which would cause a circuit to be formed of copper, zinc, and salt water. In this case the copper would cease to be acted on by the water, and would serve as a conducting plate to the zinc, which would be the substance wasted. Thus a small expenditure of zinc would come in place of a great expenditure of copper. A piece of zinc, equal to the head of a small nail, was found sufficient to protect between forty and fifty square inches of copper. The value of the application was, however, neutralised by a consequence which had not been foreseen. The protected copper bottom rapidly acquired a coating of sea-weeds and shell-fish, whose friction on the water became a serious resistance to the motion of the vessel, and it was discovered that the bitter poisonous taste of the copper surface, when oxidised, acted in preventing the adhesion of living objects. The principle, however, has been applied with success to protect the iron pans used in evaporating sea water.

159. The greatest application of the voltaic circuit is the *Electrotype;* or the process of multiplying impressions of medals, coins, engraved plates, busts, &c., which was developed about the same time by M. Jacobi of St. Petersburg and Mr. Spencer of Liverpool. It is founded on what takes place in the circle of Daniell, where a solution of sul-

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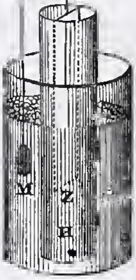
158. What was Sir H. Davy's plan for protecting ship's bottoms? What prevented its success? To what has the principle been since applied? 159. By whom was the electrotype invented?

phate of copper is in contact with the copper plate, and deposits on it metallic copper. If the original plate were of a certain form, the deposited plate would exactly fit it; and if the latter could be taken off whole, its surface would be exactly the reverse of the former. If the one were a coin in relief, the other would be a coin with a hollow impression. As the copper is deposited in a shower of the finest particles, it must completely enter all the depressions and lines of the plates, and form a surface so faithfully exact in its correspondence, that no human perception could discern a difference. The requisites of the process are, that the thing to be copied shall have a metallic surface, so that it may become the conducting plate of a circle—that something be done to prevent the coating from adhering too strongly to the original—and that the deposition should be so conducted that the deposited plate may have a close metallic texture.

160. The first discoverers confined themselves to the copying of metallic surfaces, such as copper plates and coins; but a method has been found of copying plaster of Paris, wax, wood, or any non-conducting substance, by covering the surface with black lead—a form of charcoal, which answers the purpose of a conducting plate.

161. The apparatus for copying a medal or coin consists of a cylindrical vessel, containing in it another cylinder of porous porcelain to serve as a diaphragm. Thus A is the outer cylinder; H is the diaphragm, which contains the zinc plate Z immersed in acidulated water. The outer space is filled with sulphate of copper and in it hangs the original medal M, connected by an arching wire W with the zinc, and making a voltaic circle. The medal is covered with wax or grease behind, and on the edges, or wherever the copper is not to be deposited. To prevent inseparable adhesion, the face is covered with a slight varnish. The action of the circle then

FIG. 28.



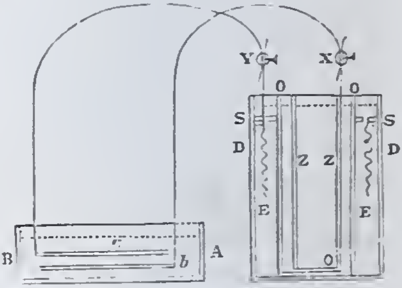
Will the copper deposited make a correct copy? Why? What is necessary to obtain a cast? 160. From what may copies be obtained? 161. Describe the apparatus for copying medals.

precipitates copper on the naked surface of the medal, and goes on adding to it as long as may be desired. If the action is slow, the coating is so much the harder. To make a good impression of tolerable thickness, one or two days are allowed. If the hollow impression thus derived is put into the circle, and itself coated, a surface will be produced in relief, which will be a perfect fac-simile of the original coin. To save the double process of making first a hollow and then a relief, a cast of the original may be taken in wax or plaster of Paris, or other fusible material; this cast will then receive a surface of black lead, or of fine copper bronze, which can be laid on with a brush. It is now a conductor, and may be inserted in the circle to receive a deposit, which will exactly resemble the original object.

162. To make gold or silver medals, solutions of salts of these metals must be substituted for the sulphate of copper. The surface deposited on requires also to be previously coated with gold or silver. The difficulty of the process is much greater with the precious metals. It requires a more powerful current to precipitate them. For silver, the solution may be nitrate, sulphate, or acetate; for gold, a very strong nitro-muriatic solution (chloride of gold) is requisite.

163. For copying engraved copper plates a larger apparatus is used: the circuit is completed with copper and zinc, like a Daniell's circle, and the deposition is made in a vessel apart, in the manner that decompositions are effected. Thus the vessel D D contains a cylinder of copper, whose place* is marked by

FIG 29.



What is done to avoid taking a double impression? 162. By what means can gold or silver be deposited? 163. For copying engraved copper plates, how is the circuit completed?

the waved lines E E; within this there is a porous cylinder O O O for a diaphragm, and within it a zinc cylinder Z Z, nearly filling the porous cylinder, but not touching it. The usual charge of liquids is applied without and within the porous partition. On the copper cylinder there rests a perforated cover S S for holding crystals of sulphate of copper, to keep the solution beneath in a state of saturation. Thus are supplied all the parts of a single circle. In a vessel apart, A B, lies the plate to be coated *b*, connected by a wire with the zinc cylinder of the circle. Another plate *c*, of oxidisable metal, faces it at a little distance, and both are immersed in the solution which is to furnish the metallic precipitate. The connecting wires proceeding from the plates in the circle are fastened tight to the wires from *b* and *c*, by screws X and Y, to make the conduction as good as possible. When the circle is closed, electricity is generated in the cylinder, and passed to the plates in the depositing vessel. The liquid between these plates is decomposed, oxygen is evolved at *c* the negative pole, and metal on *b* the positive pole. The plate *b* being prepared in the manner above described in reference to medals, by coating the back and edges with wax, to limit the deposition, and by varnishing the face to prevent adhesion, a reverse copy of its surface is procured. If the original engraved plate is employed, the plate formed from it when put into the apparatus, will be covered with a second plate identical with the original; or if a cast is first taken, an identical copy may be procured by one deposition. It is possible, by regulating the circle, to obtain a deposited plate superior to the engraved plate in the quality of impressions which it gives when printed from.

164. The improvement thus effected in the art of engraving is very great. When a copper plate is engraved, and impressions printed off from it, only the first few, called "proof impressions," possess the fineness of the engraver's delineation. The plate rapidly wears and becomes

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Describe the vessels used, and their positions with respect to each other. The position of the plate. Its preparation. The result of the deposition. 164. How has this improved engraving?

deteriorated. But by the voltaic process, the original plate can at once be multiplied into a great many plates as good as itself, and an unlimited number of the finest impressions procured.

165. Another form of applying voltaic electricity to the plastic arts, is the *voltaic etching*. The ordinary process of etching consists in covering a copper plate with a coating of wax, and by a graving-tool cutting out the sketch in the wax down to the bare copper. The portions intended to be in relief are left covered, and those to be hollowed out are laid bare. The plate is then immersed in acid, which eats away the exposed surface to some depth, but is prevented from acting on what is covered with wax. The wax is then dissolved away, and there remains a sketch in relief of the engraver's design. But by the new process, the plate, after being waxed and sketched, is immersed in the depositing vessel of the circuit, and is coated with copper wherever the wax has been cut away; and in this manner a relief surface is given corresponding to the figure that was formed in the wax. This is the opposite of the acid action, which makes the hollows where the plate is laid bare, and therefore, in engraving the surface, an opposite course has to be pursued. The wax must be cut where relief is wanted, and left where the hollows ought to be.

166. A still further extension of the art of voltaic engraving has been proposed by Kobell of Munich, by which pictures drawn in Indian ink may be multiplied. A copper plate, silvered over, is used for drawing on. The color is spread over the silver surface in such a way that the brightest lights are naked silver, and the paint is laid on according to the depth of the shadow, the strongest shadows having the thickest coating. The plate is then covered over with a wash of finely-pulverised black-lead, and put into the depositing cell, and a copper plate formed upon it. This plate will be in relief where the lights of the painting are, and hollowed in proportion to the depths of

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165. Describe the process of etching. The voltaic etching. 166. What improvement in voltaic engraving has been proposed by Kobell of Munich?

the shadows. If it is now printed from in the manner of an engraved copper plate, it will yield impressions similar to an Indian ink drawing.

167. *Gilding* and *plating* are now performed very successfully by voltaic deposition. Any metallic surface can be gilded, or silver-plated, to whatever thickness may be desired. A platinum surface can also be communicated. In this way the precious metals can have their usefulness very much extended. Plants may, in like manner, be coated over with copper, and have their forms preserved for any length of time. So baskets and wickerwork can have a metallic surface communicated to them.

ELECTRO-MAGNETISM.

168. It had long been observed that electricity was capable of producing magnetic effects. The needles of ships' compasses, when struck with lightning, always underwent a change in their magnetic character: on some occasions their poles have been reversed, what was the north before becoming the south. Disturbances of needles have also been caused by shocks from Leyden batteries. It was thus generally supposed that an intimate connection of some kind subsisted between electricity and magnetism. The discovery of the real nature of this connection was made in 1820 by Professor Oersted of Copenhagen.

169. If a magnetic needle is held along the conducting wire of a voltaic circle in action, it is made to deviate: if it is suspended along and *above* the wire, it instantly turns about and hangs directly across it: if it is next hung along and *beneath* the wire, it will deviate and lie across, but the ends will be the reverse of the former case—the end that went to one side of the wire is now on the other side: if the needle is hung along the wire *at one side*, or in the

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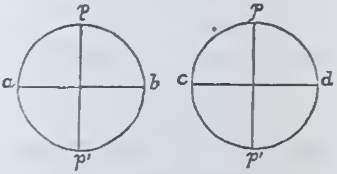
167. What surfaces may be gilded or silver-plated by voltaic deposition? What articles? 168. How was it known that a connection existed between electricity and magnetism?

same horizontal plane, it dips; one end falling beneath the level of the conducting wire, the other rising above it: if carried to the *other side* of the wire (without being reversed) it dips in the same way, but the pole that was down is now up. Thus it appears that a voltaic current has the power of acting on a needle; but that this power lies not in the direction of the wire, but *across it.* It is as if a magnetic power encompassed or circulated round the channel where electricity flows; or as if a particle, in receiving and transmitting the electrical polarity, acquired also a pair of magnetic poles and a magnetic axis, lying directly across the electric axis. Thus let there be two adjoining particles of conducting wire, and suppose that the passage of the electricity lies through them, and that, in transmitting it, *a* is positive, *b* negative, and *c* positive, and *d* negative; then drawing a cross axis *pp′*, the points *p* and *p′* are magnetic poles; or rather if a cross circle were described, the whole circumference would be magnetic; a current of magnetic attraction would go round it, so long as a current of electrical polarities went along from one to the other. Thus while the line of chemical attraction lies one way, the line of magnetic attraction is transverse to it. In chemical decompositions, the separated elements pass in the direction of the current, the attractions and repulsions which it produces on them are in its own course; but the attractions and repulsions that it exerts on magnetic bars is across or around its course. Under this singular and unexpected condition an electric current is a magnetic force. The voltaic circuit is a revolving magnet.

FIG. 30.



170. We have stated that if a needle be hung along the side of a voltaic wire, and level with it, one end will be depressed and the other elevated. If the needle has its

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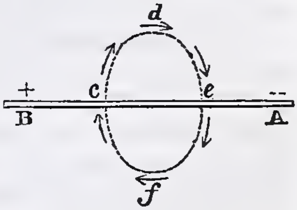
169. How is the magnetic needle affected, when held in different positions of a voltaic circle? Explain, from the figure, the direction of the magnetic current.

ends reversed, while it is kept on the same side of the wire, the same pole will be down, although pointing along the wire in the opposite direction. But if the voltaic current is reversed meanwhile, by fastening to the copper the end of the wire that came from the zinc, the dip of the needle is reversed, the raised pole is now depressed. So that the new magnetic force has a genuine polar character: a south pole circulates round the wire one way, and a north pole the opposite way, with the same current; but the reversing of the current makes a reversal of the magnetic circulation.

171. The connection between positive and negative currents, and north and south poles, is somewhat puzzling to remember. It must, in the first place, be borne in mind, that the north pole of a needle is that which points to the north pole of the earth: this designation, although erroneous, and against the laws of magnetic attraction, still continues to be used. Let A B be a portion of a conducting wire, A being the *negative* or zinc end, and B the *positive* or copper end. Then a current of positive electricity is flowing from A to B, or from right to left, and a current of negative electricity from left to right. If now the needle is held along and above the wire, its north pole will go away from the observer in the direction of the arrow at *d*: if it is held below the wire, in taking its cross position the north pole will point to the observer in the direction of the arrow *f*. When held along the wire on the same level, and between it and the observer, the north pole is elevated, as is pointed out at *c*; on the other side of the wire, the north pole is depressed as shown by the direction of the arrows at *e*. Thus while a positive current of electricity flows, from right to left, the north pole of a needle is carried round in the direction that

FIG. 31.



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170. Explain how the magnetic force of a voltaic pile has a polar character. 171. If a current of electricity pass from right to left, what direction will the north pole take? The south?

we would turn a handle with the right hand; and consequently a current of *south* magnetism flows in that direction. Or we may say that if a positive current passes before the breast from right to left, the head would represent the north pole of the attracted needle, and the feet the south pole.

172. If the wire of an electric circuit is thus a magnet, it ought to show attractions and repulsions for other electric wires. This actually takes place. If the wires of two circuits are laid alongside of each other, and are free to move, they are mutually repelled if the direction of the current is the same in both, and attracted if the currents are contrary; so that without the mediation of a steel magnet, the forces circulating round the wires are able to show themselves.

173. Nothing but a current of electricity can produce magnetic power; the charge of a Leyden battery, however intense, has no effect. But during the discharge, which makes a current to flow, the magnetism may become apparent. For magnetic purposes the *intensity* of a current avails nothing, intensity being connected with stagnation or resistance; the effect depends solely on the *quantity*. Hence batteries made up of very large circles are used in electro-magnetism. Chemical and magnetic power are both in proportion to the quantity of the excitement, without regard to its tension, or that virtue whereby it could strike a blow or force its way through resistance.

174. An apparatus has been contrived to exhibit in action the revolving power of the magnetism of the electric current. It may be so arranged that a magnet shall revolve round a wire; or, on the other hand, that a wire shall revolve about a magnet. The figure represents the method of producing both effects. M is a glass cup containing mercury, through whose bottom rises a wire from *a* the conductor of a circle. To the bottom of the cup is attached by a thread a magnetic rod *b*, which floats in the

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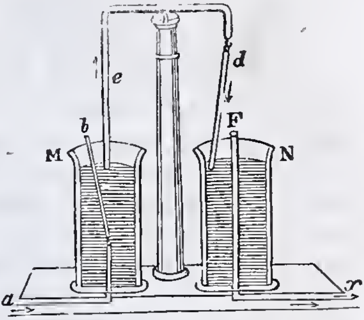
172. How are the wires of two circuits attracted and repelled?
173. What is required in electricity to produce magnetic power?
174. What is the object of the apparatus described?

mercury, and is long enough to rise above the surface. Another wire, C *e d*, coming through the pillar C from the other end of the circle, dips into the mercury, and a metallic communication is thus formed between it and the wire entering at the bottom of the cup. A current of electricity now passes along the wires and through the mercury. The upper end of the magnet *b* is within the range of the force circulating around *d*, and, being free to move, it actually revolves about the wire so long as the current continues. By the arrangement in the other half of the figure, the wire revolves round the magnet. N is a glass cup of mercury, and F a magnet fixed to the bottom, and projecting above the surface. The wire from *x* enters the bottom of the cup and touches the mercury. The wire *d* is hung from a hook, and its end dips into the mercury, which forms a metallic or conducting connection between it and the bottom wire. The circuit being closed, the magnetic action commences; the current of force circulating around the wire encounters F the pole of the magnet; there is a mutual action, but F, being fixed, the movement takes place on the wire, which describes a circle in the mercury around F. Both actions may go on from one current, circulating along *a b e* C *d x*, and the revolutions will be in the same direction; for although the current that passes up one wire passes down the other, and reverses the magnetic circulation, this is exactly met by the magnet moving in one case and the wire in the other. If the same current passed up both wires, the revolutions in this arrangement would be opposite.

FIG. 32.



175. A magnet has been made to revolve about itself by

What is the position of the magnetic rod? The effect produced by the electric current? The arrangement and effect produced in the second cup?

passing an electrical current through it, to the middle, and no farther. If the current were passed from end to end, it would urge the one end to revolve one way and the other in an opposite way, and no effect would arise ; but by confining it to one-half, the rotation is produced. This may be done by immersing it up to the middle in mercury, and passing electricity into it at the upper end. The current on descending the bar to the surface of the mercury passes off there without entering the immersed half.

176. The electro-magnetic force acts upon soft unmagnetised iron on the same principle as the ordinary magnet. Indeed its power is best developed by being inductively communicated to soft iron bars, which are magnets so long as they are under its influence. An iron bar, made magnetic in this way by an electric current, becomes an electro-magnet, and by it we can produce every effect of the common magnet.

177. A needle of soft iron, laid across a conducting wire, lies in the wire's magnetic direction, and is magnetised by induction. Bnt the action of a single straight wire upon an iron rod would be very feeble. If, however, we bend the wire round the rod, and coil it again and again, we increase the amount of the magnetic circles which act on the iron. Instead of an inch of wire communicating its influence, we may have the inductive force of many feet, and a very powerful magnetism will be imparted. It is by coiled wires, therefore, that electro-magnets are formed. A spiral coil is technically called a *helix*. Such a form possesses all the powers and properties of a magnetic bar when the electric current passes through it. It attracts and repels other magnets, communicates temporary magnetism to soft iron, by induction, and permanently magnetises steel.

178. A striking effect of the attraction of a magnetic bar by a helix is shown in the figure, which represents a coil ending in two little cups P and *p*, where the communications are made with the poles of the battery : a small portion of mer-

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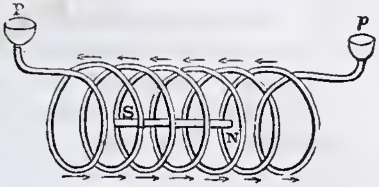
175. How may a magnet be made to revolve about itself? 176. Upon what will the electro-magnetic force act? 177. What is a helix? How, and on what principle, is it used?

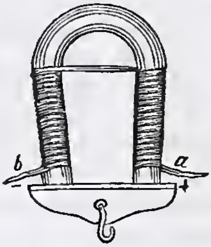
cury is poured into each cup, and the battery wires are dipped in the mercury, which thus forms a very perfect metallic junction. If a magnet S N is laid in the coil, and the circle completed, the action is such that the magnet starts up and suspends itself in air in the centre of the hollow, and hangs there so long as the electricity circulates. The opposing actions of the different ends and sides of the wire so neutralise each other, that it is not drawn either out or in, or nearer to one side than to another; and its only position of rest is a nearly central station; its own weight necessarily adds to the downward tendency, and keeps it a little below the axis of the spiral.

FIG. 33.



179. In communicating temporary magnetism to a soft iron bar, with the view of forming the electro-magnet, we may choose either a straight bar or a horse-shoe: the latter is represented in the figure :—The wire *a* from one pole of the circuit, is coiled round and round the iron many times, and goes off at *b* to join the other pole. If the positive current pass in at *a*, *a* will be the north pole of the magnet, and *b* the south, according to the rule already laid down. To make a powerful magnet, the copper wire should be thick, and covered with silk, to prevent the electricity from passing sideways from one coil to another, or to the iron bar. A lifter is attached for the suspension of weights. An electro-magnet may be made of far greater power than an ordinary magnet of the same size. A horse-shoe, whose arms are eighteen inches long, and two inches thick, may be

FIG. 34.



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178. Describe the position taken by the magnet in Fig. 33. 179. What kind of wire is used to make an electro-magnet? What weight may a horse-shoe, eighteen inches long and two inches thick, sustain?

made to sustain 1000 lbs. if a strong current is passed through it.

180. To determine which is the north and which the south pole of an electro-magnet, we can revert to the action already described of a straight wire on a needle. If a wire lies before us across our breast, and if a positive current passes from right to left, the needle's north pole is made to describe a right handed circle, that is, the south pole of the wire's magnetism goes round in the circle in which the right hand would move a winch. If, therefore, a soft rod lies up and down on the other side of the wire from us, its lower end will be south and its upper end north, these being the poles of the wire's revolving action. If the wire is now coiled round it while it stands upright, the effect will continue the same, so long as positive electricity passes from right to left along the coil between our breast and the bar. Suppose we clasp our arms round a tree, and that a positive current circulates from the right hand along the right arm across the breast to the left; in this case the top of the tree would represent the north pole and the root the south.

181. If a steel needle or bar is laid in the inside of a helix, and a strong current passed along, it will acquire a permanent magnetism. The helix which answers best for this purpose is a short thick coil, formed by first winding the wire into one spiral, and then laying upon it a second layer, and then a third, and so on till a great thickness is reached. A powerful current is sent through it, and the bar inserted and moved once forward its whole length, then backward till its middle is in the centre of the coil; the current is then stopped, and the bar taken out perfectly magnetised.

182. Thus the electro-magnetic power is in all respects identical with the loadstone and the earth's magnetism; only it can be raised to a much higher degree of intensity than ordinary magnetism. By using a strong battery of

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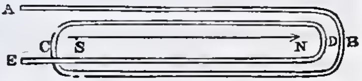
180. How is the north or south pole of an electro-magnet determined? 181. How may a steel bar be magnetised? 182. In what does an electro-magnet differ from loadstone?

Grove's construction, a mechanical force can be developed which is perfectly enormous. There is scarcely any limit to the power which may thus be created. The wire in contact with the iron may, by successive coilings, layer above layer, be extended to hundreds of feet; and if the battery is powerful enough to send the current through the entire length, the magnetism is increased in proportion to the quantity of the wire accumulated round it.

183. The electro-magnetic action has been applied to form an electrometer of a very delicate kind, which is essential in experimenting with voltaic currents and electricity of weak tension. It is the proper voltaic electrometer or *galvanometer*. If a magnetic needle S N is suspended within several bendings of a conducting wire A B C D E, and hung parallel with the wires, the setting on of the current will make it deviate and lie across; it will thus be a visible mark of the passage of electricity. It will be turned aside by nearly four times the force that would be exerted by a single wire; hence the apparatus has been called a *multiplier*. But instead of two circles of coil, fifty or a hundred may be made, forming a helix with an oval section, and within this the needle is hung. When the instrument is used, it is placed so that the direction of the helix is in the magnetic meridian; hence the needle will, under the earth's attraction alone, lie exactly alongside of the wires. When the current is set on, a deviation will take place; but the needle will not be carried so far as to lie directly across, unless the current be as strong as completely to overcome its polarity to the earth, and its own inertia and the resistance of the suspension. With a weak current, the deviation may be very trifling, but as the current increases in strength, it becomes greater; hence the angle described is a measure of the power of the charge sent through the wire.

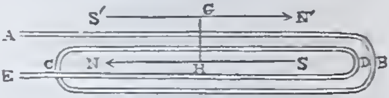
FIG. 35.



In what proportion is the magnetism increased? 183. Describe the galvanometer. In what way is the intensity of the electric current measured?

184. An improvement has been made upon the instrument, which gets rid of the action of the earth's magnetism, and consequently leaves the needle more free to move aside under the influence of the electrified helix. Instead of one needle hanging within, two needles are used, one within and the other above the oval coil; the upper one having its poles lying reverse to the lower, as in the figure. N S is the inner needle, S′ N′ the outer; being on different sides of the set of wires, they would deviate in opposite ways if their poles were in the same direction; but the reversal of the poles causes different sides of the current to move them both in one direction. The two may therefore be fixed on one axis of suspension, and they will act under the influence of current as a single needle. But the earth's magnetism will of course affect each of them; since, however, they lie in opposite directions, it will tend to draw N′ one way, and S′ which is on the same end, the other way; and the two attractions will neutralise each other, so that no movement will arise from the operation of the earth's magnetism, if the needles have exactly the same degree of polarity. It is unnecessary with this instrument to attend to a meridian position; and the deviation will be much greater from any given current than with the single needle; consequently the indications will be more delicate. By this instrument very feeble currents can be made apparent.

FIG. 36.



185. For measuring the force of powerful currents, it is not necessary to coil the wire or to use a silk thread for suspending the needle. A single coil placed in the magnetic meredian, and enclosing a needle on a point, will serve to measure the strength of such currents. The stronger the current, the more will it overpower the tendency of the needle to point to the north, and hence the angle of devia-

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184. How is the action of the earth's magnetism avoided? Describe the instrument. What makes this a delicate measurer? 185. How may the strength of powerful currents be measured?

tion from the direction of the coil or the magnetic meridian will correspond to the strength of the circulating electricity.

ELECTRO-MAGNETIC MACHINES.

186. Many important practical applications have been made of the voltaic magnetism. Of these the most prominent is the Electrical Telegraph, invented by Professor Wheatstone, and perfected by him and others, and now in extensive operation over the lines of railways.

187. The electrical telegraph depends on the power of an electric current to cause the deviation of a magnetic needle, and on the great distance that the power may be conveyed. In the experiments of Mr. Wheatstone, it appeared that a current could be transmitted through four hundred miles of wire without being extinguished; so that at the end of that distance it could cause a sensible magnetic action.

188. The apparatus of the telegraph consists, in the first place, of a line of conducting wire suspended on poles, and reaching from station to station. On the first introduction of the telegraph, a pair of parallel wires was thought necessary, in order to complete the voltaic circle; but it is now found that the earth can make the returning part of the circuit, and that it may therefore be formed by means of a single wire. At each end, the wire is carried down to the ground, and attached to a large plate of metal buried there; and the current finds its way through the earth from one of the metallic masses to the other. The wire is formed of iron coated with zinc by a particular process, and receives the name of galvanised iron wire; it rests on the poles in earthenware tubes, in order to insulate the passing electricity.

189. The second essential of the telegraph is the *battery*. The kind of battery which seems to answer best is the partitioned trough, with a pair of copper and zinc plates in each cell. The cells are filled with dry sand, which is

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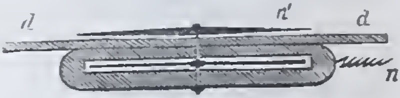
187. On what does the electric telegraph depend? 188. What was thought necessary on its introduction? What plan was afterwards adopted? Of what is the wire made? 189. What battery is used?

moistened with dilute sulphuric acid when it is to be set in action. This arrangement is found to yield a very constant and enduring voltaic current. The greater the distance between the stations, or the longer the circuit, the more powerful of course must the battery be. The resistance to the current necessarily increases with the length of the wire, and at a certain distance it would be too feeble to produce a deviation of the needle, or any other palpable movement.

190. The third necessary part of the telegraph circuit is the *needles*. These are the indicators of the excitement, and the instrument with which the signs are made. In order that the current may deflect a needle forcibly, an oval coil is formed on the principle of the galvanometer; and two needles are used, one within the coil and one without, as in the figure, which gives a side view of the instrument, *n* being the inner needle, and *n′* the outer. As in the galvanometer, the needles are arranged with their opposite poles together, so that the earth's magnetic action upon them is neutralised; and from their being on different sides of the coil, they are both moved in one way by the same current *n′* is the needle that is visible, and it lies upon a dial-plate *d d*, seen edgeways in the figure The helix or coil makes part of the great circle; and when the battery is in operation, and the circuit closed, the needle is moved across the coil, or deflects from the upright position which it occupies when unexcited. If several needles are mounted on one circuit, all will be moved in the same way at the same instant.

FIG 37



191. The fourth essential part of the machinery is an apparatus for making and breaking the metallic contact, or closing and opening the circuit, and also for reversing the current, so as to give an opposite deflection of the needle,

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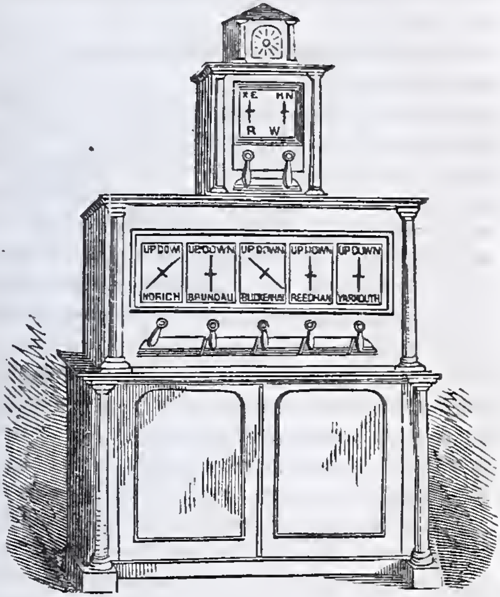
In proportion to what, must the power of the battery be increased? 190. For what are the needles used? How are they placed? 191. What is the fourth part of the machinery?

and thus vary the signal. This has been executed in several ways. The external instrument is a handle that may be swayed to the right or left, according to the deflection to be given to the needle. The accompanying cut represents the Norwich Railway apparatus, with its needles and handles; a separate wire and circuit being necessary for each needle. So few as two needles have, however, been found sufficient to make all the requisite communications The needle to the left is seen deflected one way and that in the middle the opposite way. An agreement must be made as to the meanings represented by each deflection or combination of deflections. Thus in a double needle apparatus, each letter of the alphabet and each arbitrary sign must have a different aspect; and yet there are only four simple movements which can be made—namely, a right and left deviation of each needle; the combinations of these movements would give in all twelve distinct configurations of the needles. But by repeating the vibrations, any number of different signals may be made—that is, each needle may

FIG. 38.



What does the cut represent? In what position does it exhibit the needles? Must each letter of the alphabet be shown differently? How many simple movements can be made? How many combinations?

be deflected once, twice, or thrice for the same signal; a pause being allowed after the signal is completed, to distinguish between the successive deflections of one sign and the transition to another. At the end of a word a particular sign is made to show that it has been completed. It is found possible to communicate at the rate of fifty letters a minute.

192. The apparatus for signalling may be very various, and many schemes have been proposed with the view of quickening the process of communication. Bain's new system consists of causing the electric circuit to make colored spots in a piece of paper soaked with sulphuric acid and prussiate of potash; employing the chemical instead of the mechanical action of the voltaic circle to make the indications. The moistened paper is wound in a metallic roller, which is kept moving while the end of a metallic spring rests upon it; the apparatus forming a part of the great telegraph circle. While the circle is broken, no effect is produced; but when it is closed, the current passing through the wet paper effects a decomposition that shows itself in a blue spot. At the other end of the line an apparatus of a similar kind is placed; but the strip of paper is dry and acts as an insulator. It has holes punched in it, which, in the course of the movement, come under the spring, and allow it to touch the naked roller, and make a perfect metallic contact, and thereby close the circle. At the instant, therefore, a hole passes beneath the spring at one end, a colored spot appears beneath the spring in the apparatus at the other end; so that the series of holes are exactly represented in a series of blue spots. If, therefore, aggregations of holes are chosen to represent letters and signs, these can be faithfully repeated and read; and the apparatus can be driven with far greater rapidity than the needle system.

193 Although the telegraph is by far the greatest application of voltaic electricity and electro-magnetism, it is

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What is done at the end of a word? At what rate can letters be sent? 192 In what does Bain's system consist? How is the circle broken? How closed? What represents the letters?

not the only application. Much ingenuity has been spent in contriving machines for bringing electricity into play as a prime mover, like wind, water, steam, or gunpowder. The mechanical force of an electro-magnet, as we have seen, is very great; and there seems no reason why it should not be used as a source of power in moving machinery. Whether it would be as cheap or cheaper than steam-power, must depend on many considerations. But all events it might be found preferable to other prime movers in special cases and circumstances. As yet, however, no effective method has been contrived for bringing the power to bear upon machinery. It has the peculiar character of being a very intense force acting through short distances; and it is requisite that this mode of action should be converted into a rotatory motion, in order to be generally applicable to movements. An apparatus has to be formed which will do the same for the magnetic attraction that Watt contrived for the expansive force of steam, when he joined together a cylinder and piston, parallel motion, cross-beam and crank, to convert the reciprocating steam-pressure into a wheel movement. The magnetic force is also a reciprocating force, but of very short range and varying power; and some suitable apparatus must be interposed to transmit its whole amount to the steady whirl of a shaft or axis. The machines hitherto contrived have not been able to communicate the whole power of the magnets to the rotatory apparatus, and they are therefore no fair criterion of the mechanical force which may be obtained from the consumption of zinc and acids in a voltaic circle.

194. Mr. Bain has succeeded in applying electricity to move the pendulums and machinery of clocks. For the ball of the pendulum he makes a hollow coil of copper wire, whose opening or axis looks right and left, or in the direction which the pendulum swings. Two magnets are fixed so as to point into the opposite ends of the coil, and

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193. What is the character of the electro-magnetic force? What is requisite to adapt it to machinery? In what does it resemble steam power? 194. To what has Mr. Bain applied electricity?

face each other. If a current of electricity is sent through the coil, it becomes an electro-magnet, and is attracted to the nearest magnet. Accordingly, means are provided for communicating at every vibration a current to the pendulum, and for cutting it off while it passes the middle line, and recommunicating it at the other end of the sweep. A plate of zinc and a plate of copper are buried, facing each other, in the earth at a depth of at least nine feet, that there may be a constant supply of moisture. The damp earth is thus the exciting element of the circle, which has a permanent action. Wires are carried from the plates, and passed along the pendulum, to connect with the coil which forms its ball. About the middle of the pendulum rod, an arrangement is made whereby the motion of the pendulum closes, breaks, and recloses the current according to the place where it lies in its vibration. The attraction of the magnets is thus made to sustain its motion and the motion of the connected wheelwork. It may be regulated to beat exact seconds like an ordinary pendulum.

MORSE'S ELECTRO-MAGNETIC TELEGRAPH. *

195. From the description which has now been given of the electro-magnetic power, it will readily be perceived that a great force can be made to act, simply by bringing a wire into contact with another conductor, and that the force can be instantly arrested in its operation by removing the wire from the contact; in other words, that by connecting and disconnecting a helix with a battery a prodigious power can be made successively to act and cease to act. Advantage has been taken of this principle in the construction of the American electro-magnetic telegraph, which was matured by Professor Morse, and first put into

* This description is taken from Parkers's Natural and Experimental Philosophy; Twenty-first edition, New-York, 1849.

What is the exciting element of the current? How is the motion of the pendulum arranged for? 195. How may the electro-magnetic force be made to act? How arrested?

operation between the cities of Baltimore and Washington, in 1844. The principles of its construction may be briefly stated as follows ;—

196. An electro-magnet is so arranged with its armature, that when the armature is attracted it communicates its motion to a lever, to which a blunt point is attached, which marks a narrow strip of paper, drawn under it by machinery resembling clock-work, whenever the electro-magnet is in action. When the electro-magnet ceases to act, the armature falls, and communicating its motion to the lever, the blunt point is removed from its contact with the paper. By this means, if one of the wires from the battery is attached to the screw-cup, whenever the other wire is attached to the remaining cup, the armature is powerfully attracted by the magnet, and the point on the lever presses the paper into the groove of a roller, thereby making an indentation on the paper corresponding in length to the time during which the contact with the battery is maintained, the paper being drawn slowly under the roller.

197. An alphabet of signs or symbols, is formed by indentations of the paper varying in length, which is easily read by those connected with the telegraph. Thus, the letter *e* is represented by one short mark thus -; the letter *o*, by two marks thus - -; the letter *a*, by a short and a long one thus - —; the letter *f* by a short, a long, and a short one thus - — -; the figure 1 by a short, two long, and a short one, thus - — — -. By such an arrangement all the letters and the numerals are represented by the telegraph. A simple contrivance connected with the machinery causes a bell to strike when the telegraph commences its operations, and thus gives warning to the attendant.

The following table presents a view of Morse's Telegraphic Alphabet :—

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196. Explain the position of the paper. The manner of marking upon it. Of ceasing to mark. 197. How is the alphabet formed? What represents the letter *e*? The letter *o*? The letter *a*?

A - —   B — - - -   C - - -   D — - -   E -
F - — -   G — — -   H - - - -   I -   J — - —
K — - —   L ——   M — —   N — -   O - -
P - - - - -   Q - - — -   R - - -   S - - -   T —
U — -   V - - - —   W - — —   X - — - -   Y - - -
Z - - - -   & - - - -   &c. - - - - - - -

Numerals.

1 - — — -   2 - - — - -   3 - - - — -   4 - - - - —   5 — — —
6 - - - - - -   7 — — - -   8 — - - - -   9 — - - —   0 ——

MAGNETO-ELECTRICITY.

198. Magneto-electricity is the counterpart of electro-magnetism: the one explains the production of magnetism by an electric current; the other shows how an electric current may be produced from a magnet. This branch of the science was created by Professor Faraday.

199. If an electric current and the magnetism of a bar are so closely allied that the first can give rise to the second, it was natural to expect that the second should be able to cause the first; or that a magnet might be so placed with reference to a conducting wire, as to produce in it a current of electricity. The experiment may be tried in many ways. Thus since a helix charged with a current can magnetise a bar lying in it, let us take a bar magnet and put it into a coil which has no connection with a voltaic circuit, but whose ends terminate in a galvanometer, and which forms a complete circle of conducting wire. We have now an active magnet lying in an unactive helix; but no current is observed. Although the active magnet is in the very place where an unactive bar would be magnetised by an active wire, yet the circumstances being reversed, the active magnet cannot induce magnetic currents around the wire, so as to make electric

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198. What is magneto-electricity? By whom was it discovered? 199. What would be inferred from the principles of electro-magnetism? If a magnet lies in a helix, what will result?

currents run along it. Let us, however, seize hold of the magnet, and instead of its lying at rest in the hollow of the coil, let it be moved backwards or forwards; a current is immediately observed, the needle of the electrometer being sensibly deflected. While we continue to move the magnet in or out, the current is maintained: when we let it rest, the current ceases: so that an active magnet has the power of creating electric currents, if it is moved in the direction of its length across a wire or assemblage of wires. The motion of the bar is essential to the effect. The necessity of motion is owing to the character of the magnetism of a conducting wire; for this magnetism is not a reposing or statical magnetism, but a current or revolving magnetism; and unless the statical magnet is itself set in motion, it cannot be the cause of a current magnetism. The electricity arising from this action is called Magneto-Electricity.

200. If an active wire, in connection with a circuit, lies alongside of another wire that is inactive and connected with a galvanometer, the current of the first has no influence in making a current in the second while both wires are at rest; but at the instant the current is arrested, and the instant that it is set on upon the first wire, a momentary current appears on the second. While the current continues, there is no action. Let, however, the wires be made to approach each other, and a current ensues on the inactive wire; when the wires are at a stand still it ceases. Or if they are drawn away from each other, a current in like manner arises, but opposite to the current during the approach; so that there are two methods of passing a current from an active to an inactive circle. We may either close or break the active circle, and thereby create an instantaneous current; or we may move the wires nearer or farther from each other, and during either motion we have a current on the inactive circle; the approach making it in one direction, the recession making it in the opposite direction. These

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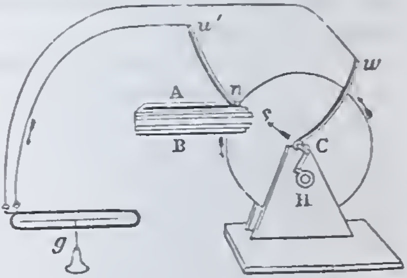
If the magnet is moved, what will be the effect? 200. If an active and inactive wire lie beside each other, when may currents be induced? What are these effects called?

effects are designated by the term Volta-Electric-Induction; and the currents Induction Currents.

201. The approximation or separation of the wires is exactly similar to the moving of the magnet in the coil, or across a wire. An active wire is a magnet, and if it is moved sideways towards another wire, the effect is the same as if a magnetic bar were moved endways. The side motion of the one can do exactly what the longitudinal motion of the other can do. In both cases mere proximity has no effect; but, by movement, each can excite a current in a dead circle.

202. Faraday was able to produce a permanent electric current from a horse-shoe magnet by the following apparatus:—

FIG 39.



A circular plate of copper C is made to revolve upright on a stand, and a handle H is fixed on the axis. Two conducting wires *w* and *w′* are connected at one extremity with the galvanometer *g*, by being plunged in its mercury cups. At their other extremities one of them. *w*, is connected with the axis of the copper plate: the other, *w′*, is made to touch its edge between *n* and *s*, the poles of the magnet A B, placed as represented in the figure. The plate is whirled by means of the handle, and a current of electricity is found to circulate round the wires; the nature of the current is reversed when the motion is reversed. The inductive effect being the same whether a magnet is moved along a conductor or a conductor along a magnet, the action is produced here by the copper edge constantly running across the direction of the iron. A current thus arises on the

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201. What does the moving of the wires resemble? 202. Describe Faraday's apparatus for producing an electric current. What are its operations and their effects?

edge and passes inward to the axis, and thence along the wire *w* to the electrometer, the opposite current taking the contrary course. When the handle is revolved from right to left, the positive current in the above apparatus has the direction of the arrows. The end of a bar magnet, held near the edge of the revolving copper, has the same effect as the horse-shoe.

203. The identity of electricity and magnetism was still farther confirmed when Faraday discovered that a spark could be drawn from the magnet. At the moment of making or breaking the magnetic contact, or when the lifter either completes the connection or breaks it, a spark is sent forth at the junction; or if the lifter is surrounded with a helix, the spark may be seen in the circle, by having at one part of it two surfaces very near, but not in contact—as a fine point almost touching a surface of mercury. The instant the lifter strikes the ends of the horse-shoe, or the instant it is drawn away, a spark passes through the open interval of the circuit.

204. An induced current, either from a magnet or from an active circle, produces a sensible shock, of the voltaic character, but more severe. Its intensity is higher than the intensity of the original current. When the induction is of the temporary kind which accompanies the opening and closing of the active circle, the shock is instantaneous; but by keeping up a constant induced current by movement, a continuous shock of a very painful kind may be communicated. Machines have been constructed for producing the permanent induction, called Magneto-Electric Machines; and in causing physiological effects, or for acting on the human body, they are the most efficacious of all electrical machines. Their principle is different from the revolving apparatus of Faraday above described. They are contrived so that a lifter may repeatedly make and break its contact with the magnet, and thus induce a succession of currents upon a circle of wire coiled many times

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203. What further identified magnetism and electricity? When does this effect appear? 204. When is a shock produced? When is this instantaneous? When continuous?

round it. The lifter is made as if for an electro-magnet—in other words, it is wrapped round with a great many turns of wire; but the coiling is made so that the ends of the magnet point as it were into the hollow of the coil—that is, the lifter is not simply a cross bar, but has across its ends two cylinders, facing the ends of the horse-shoe, and receiving the wire coils. If the magnet is now rapidly revolved on an axis running between its legs, the constant movement of approach and retreat from the coiled lifter maintains a series of currents, and these are twice reversed at each revolution: for one kind of current arises when one pole approaches one end of the lifter, and an opposite when this pole leaves it and the other pole approaches. This incessant reversal of the current is probably the cause of the very painful character of such currents when transmitted through the arms. The wires of the coil terminate in small copper cylinders, which are held one in each hand; and if the hands are previously moistened with salt water, the shock will be experienced to the fullest advantage. The more rapidly the magnet is whirled, the more intense will be the action.

205. The machines first constructed made the magnet to revolve as above described; but subsequently they were formed so as to make the coiled lifter revolve, while the magnet remained fixed. The apparatus is so arranged that the shock passes upon the circle through the body only when the keeper faces the ends of the magnet; when the keeper leaves the poles, the connection is broken, and remains broken till half a revolution takes place, when the opposite current is induced as a shock, and instantly stopped. Thus there is given a succession of disjoined and contradictory shocks.

206. Chemical decomposition has been effected by magneto-electricity; but as this demands a copious quantity of the current, it requires large magnets to make it apparent. The machines are generally compound horse-shoe magnets

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How is the lifter formed in a magneto-electric machine? What is the operation of the machine? 205. In what respect do later machines differ from this?

of large dimensions. The wire coiled on the cylindrical branches of the keeper is very long, sometimes many hundred yards. For chemical decomposition an arrangement is adopted, called the *quantity* arrangement, for securing a continuous current in the same direction, as no decomposition arises when the electricity is continually interrupted and reversed; the one polarity must necessarily counteract the other. Hence the machines which give the most violent shocks are sometimes totally inefficacious in decomposing compounds.

207. As the earth is a magnet, it ought to have the same power as other magnets to induce electric currents. Faraday succeeded in proving this to be the case, by making the same arrangements as were necessary for a portable bar. A conducting circle is made to revolve across the direction of the earth's magnetic pole, or at right angles to the dipping needle, and in this way it acquires an electric current, which can be distinctly made evident by the galvanometer. Hence Faraday inferred that voltaic currents must be frequently generated by the accidental movements which take place on the earth. Thus in high north latitudes, where the pole lies almost vertically down, a wheel revolving horizontally would be moving across the magnetic direction, and would have a current induced upon it. So even running water in the polar regions would experience voltaic excitement from the earth's magnetism.

THERMO-ELECTRICITY.

208. It has been seen that an electric current, passing through an inferior conductor, or in any way interrupted without being completely checked, gives forth heat. Resistance to its passage is the means of converting the polar excitement into an increased temperature of the resisting

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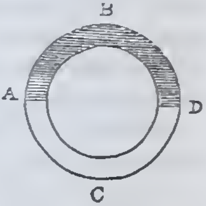
206. What arrangement is made to produce chemical decomposition? 207. What did Faraday prove in regard to the earth? What infer from this? 208. When does electricity produce heat?

material. On this condition heat and electricity are reciprocal. But although it has always been very easy to produce heat by an electric current, it was only in 1832 that the means were found of producing an electric current, by heat. This discovery, made by Professor Seebeck of Berlin, gave rise to the science of Thermo-Electricity, which completed the evidence of the reciprocity of the electrical and the other effects. Volta had produced the excitement by chemical action, Professor Faraday from the magnet, and now it is derived from heat; its three greatest effects are thus found to be in turn its causes.

209 When two metals whose susceptibility to heat is unequal are soldered together, and heated at the joining, an electric current is evolved. Thus if A B C D be a metallic circle, the one half, A B C, being *bismuth*, the other half *copper*, and if a lamp be applied at A, one of the joinings, it will heat both metals, and cause electric currents to flow round the circle. A positive current will pass from the bismuth to the copper, or round in the direction A B C D, the negative taking the opposite course. Thus when two substances, differently disposed in regard to the reception of heat, are heated together at their point of contact, the discrepancy shows itself in the two metals polarising each other, and yielding electricity.

FIG. 40.

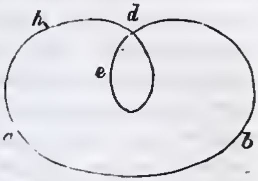


210. If we heat a wire which makes part of a circle attached to the galvanometer, the heat will be conducted off right and left along the wire, at an equal rate, and no electricity will arise. But if in anyway we cause the heat to pass round more copiously to one side than to the other, a current will be made apparent. Thus if we make a loop upon the wire, and make it touch at the crossing, this will retard the passage of the heat to the side where the loop is, and thereby disengage electricity or polarise the wires.

What discovery was made by Professor Seebeck? What causes are now known to produce electricity? 209. When will two metals evolve electricity? Give an example. When a wire?

Thus suppose the heat applied at *h*; it will be conducted along the wire each way; but at the loop *d*, part will go along *d b*, the proper direction, and part will be communicated to *d e*, which will make it return again towards *h*, and, on the whole, impede the conduction on the way to *b* So that the heat will travel at a greater rate round by *a* than round by *b*; and it would appear that when unequal currents of heat encounter, they issue, not in a simple increase of one another, but in a polar effect, or they make an active voltaic circuit. On the same principle, if one end of the wire is oxidised, it will be made a worse conductor, and electricity will be manifested. A crystallised body may sometimes produce a current on the application of heat, owing to the fact, that the heat passes more easily through one side than through another in some crystals.

FIG. 41



211. It is found that when hot water mixes with cold water, electricity is produced; the hot liquor being negative and the cold positive. Other liquids show a similar action; but the kinds of excitement are not invariable: a hot acid mixed with a cold acid makes the first positive and the second negative. Hence it appears that the passage of heat must in general cause electrical polarity; only if two equal portions of heat pass round in a circle and meet, they will neutralise each other's effects, and no excitement will be apparent.

212. If, instead of bismuth and copper, bismuth and antimony are soldered together, the effect will be greater, the disparity of the metals being greater. This last couple is what is usually adopted for a thermo-electric circle, being superior to any other that could be chosen. The following table exhibits the order of the principal metals in regard to thermo-electric combinations:—

When may a crystalised body produce a current? 211. What is observed of the mixture of hot and cold liquids? 212. What metals are usually chosen to make a thermo-electric circle?

Bismuth
Mercury
Nickel
Platinum
Lead
Tin
Copper
Silver
Gold
Zinc
Iron
Antimony

The farther asunder two metals are in this table, the more powerful is the couple formed by them. Bismuth and iron would make the next best couple to bismuth and antimony. Silver, gold, and zinc are very nearly equal in the effects which they would cause if coupled with a metal from the other end of the table. Each metal causes a positive current to pass upon any metal beneath it, and a negative upon any metal above it. Thus if platinum and copper were soldered together, a positive current would pass from the platinum to the copper, and the negative from the copper to the platinum; or the actual state of each would be—platinum negative, copper positive; that is to say, if two plates were laid on each other, and heated at the joining, the free side of the platinum would be negative, and the free side of the copper positive. Positive electricity radiates from the joining through the copper mass, negative electricity through the platinum mass.

213. Various mineral substances may enter into the thermo-electric circle, such as plumbago, peroxide of manganese, per-sulphuret of iron, and galena. Plumbago is positive to platinum, and stands pretty near the lower end of the table. The per-sulphurets stand near to bismuth

214. The order of the metals above given does not correspond with their goodness as conductors of heat. Bismuth, indeed, and the metals near it, are the worst conductors of heat; while some of the metals near the other end, such as gold, silver, and copper, are among the best conductors. But there are very decided exceptions. Platinum ranks with gold and silver in conducting power, but it is far removed from them in the thermo-electric series. Iron is inferior as a conductor to all of these, and yet it is nearer the antimony than any of them. It cannot, therefore, be laid down as a rule that the worst conductors of

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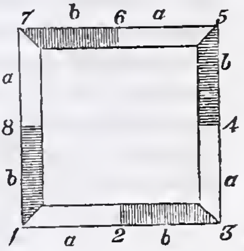
How are the metals arranged in the table? 213. What mineral substances may enter into the thermo-electric circle? 214. Does the electric power of metals correspond to their capacity as conductors?

heat rank highest in the thermo-electric series, or that a good and a bad conductor will make an effective couple.

215. But if we classify metals according to their power of radiating heat, or of receiving it by radiation, we find a near coincidence with the above order. A metal does not radiate heat from its surface in the same proportion that it passes it through its substance; the proportion is more nearly an inverse proportion. The worst radiators are at the top of the table, and the best radiators at the bottom. Hence it appears that when heat is applied to the joining of two metals, and when the one is slow at receiving the imparted heat, while the other receives it abundantly, the inequality thence arising is the cause of the electricity. For the heat applied to the couple being that from a lamp or a fire, it is communicated by radiation; and as bodies which radiate well, receive radiant heat equally well, the best radiator will be most heated, and will be negative, and the other positive; so that in general the side of the joining where most heat is received is the negative side, and through it the negative current passes to the wire of the circuit.

216. A single circle, made of a bar of bismuth and one of antimony, soldered together, makes a simple circuit or couple; but any number of bars may be laid together, so as to make a compound thermo-electric circuit. If they are joined one to the other in a long line, or in a circle, the heat will have to be applied to every second joining. If the first, third, fifth, and seventh joinings are heated, while the second, fourth, sixth, and eighth are cooled, by being laid in ice, the force of the current will be increased. Cold has the same power of exciting electricity as heat, only the current is reversed. The figure represents a compound circuit of four bars

FIG. 42.



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215. How does the classification of metals, as radiators, correspond to the arrangement of the table? 216. Where will heat be applied in the figure? What effect is produced by cold?

of bismuth *b*, alternating with four bars of antimony *a*. Heat would have to be communicated either to the four corners or to the middles of the four sides. If the corners were heated and the middles iced, the effect would be thereby increased.

217. A series of bars of alternate bismuth and antimony may be, as it were, folded together in a bundle, the first, third, fifth, seventh, &c. joinings being at one end, and the second, fourth, &c. at the other end: the bars being kept from touching at their sides by an insulating substance. The last rod of bismuth is connected with a wire, and forms the negative pole; and the wire attached to the last rod of antimony at the other end will be the positive pole. The two ends of the bundle are blackened to increase their absorption. If either face is heated, a current will arise; if one is heated and the other cooled, the current will be greater; if both are heated alike, there will be no current.

218. Such a bundle of bismuth and antimony needles has been constructed to serve as a thermometer for delicate experiments on heat. Differences of temperature that are imperceptible by the mercury or alcohol thermometer, are found to effect the galvanometer of a thermo-electric pile. Radiant heat especially can be detected with extraordinary accuracy by exposing one end of the bundle to the heating rays.

219. The current circulating in the thermo-electric circle is of weak intensity compared even with the voltaic pile, and therefore it is not adapted for giving shocks. But the quantity which it yields may be very great, and it is capable of decomposing chemical compounds. Also, by using a bundle of thirty elements or pairs about an inch thick, and heating one end by a hot iron placed near, and cooling the other with ice, the intensity of the current is sufficient to make a distinct *spark* in daylight, when the circle is broken or closed.

220. The discovery of thermo-electricity suggests an

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217 How is a series of bars of bismuth and antimony arranged? How is a current produced? 218 For what is such a bundle used? 219. How may a spark be caused?

explanation of the probable origin of the earth's magnetism. The sun's rays heating the earth in one place after another in his daily circle, would cause an electric current to circulate round the globe in an equatorial direction, or more strictly, in the direction of his path. If we suppose him for a moment standing over any one place, it is obvious that the portion of the earth to the east of that place is hotter than the westerly portion ; because what he has been recently shining on must be warmer than the ground he is only approaching to shine on after a day's absence. But we have seen that, in the thermo-electric circuit, negative electricity flows from the joining to the hot side, and positive electricity to the cold side ; therefore the motion of the sun from east to west will cause a positive current to move in the same direction, and a negative current from west to east. But if we refer to the rule for determining what would be the magnetic polarity of the earth arising from such a current according to the laws of electro-magnetism, we find that it would give to each hemisphere the same kind of polarity as they actually have. If the daily path of the sun were from west to east, the earth's magnetism would be the reverse of what it is : so that the sun's heat circulating round the globe will necessarily magnetise the earth. The daily and yearly fluctuations of the needle also tend to show the connection of terrestrial magnetism with the sun's motions. It may therefore be said that the sun is the great source of all power on the earth. It gives warmth, supports vegetation, draws up the water to the clouds, originates the thunder and lightning, and produces magnetism and all its consequences. The earth's own forces of gravitation and cohesion, and its attractions in general, tend to aggregate, solidify, and condense the whole of its substance into a compact heap of lifeless matter ; the sun supplies the counteractives of these, and causes expansion, separation, decomposition, and all the agencies which lead to the renewal of movement and life.

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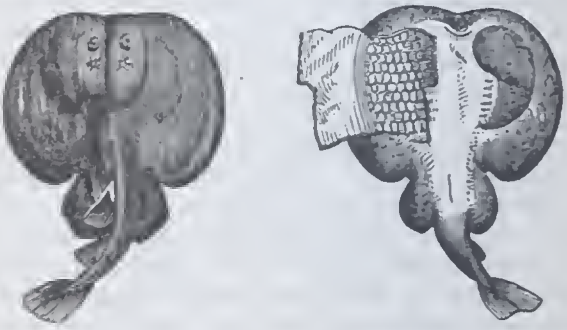
220. What way will the sun's motion cause the electric currents to flow? Why? What is the tendency of the earth's attractions? What effects are caused by the sun's action?

ANIMAL ELECTRICITY.

221. This branch of the science refers to the production of electricity by living bodies, and gives an account of certain animals that possess within their structure special organs for generating electric currents; it may also include what is known of the effects of electricity on the animal system. The former subject would be named Animalo-Electricity, if we followed the analogy of the preceding names—Magneto-Electricity, Thermo-Electricity.

222. There is a flat fish found on the shores of the Mediterranean, and on the Atlantic coast of France, which has been known from antiquity to give benumbing shocks to any one who handles it. It is called the *Torpedo.* When dissected, there are found in it two organs, or masses of honeycomb structure, (see fig.) one on each side of the body at its broadest part, or near the head. In an animal 18 inches long, 12 broad, and 2 thick, each organ is about 5 inches long; the breadth is 3 inches at the head, and at the other end half an inch; being, as it were, triangular, the narrow end pointing to the tail. They occupy the whole thickness of the fish from breast to back, as far as they extend; they consist of a mass of roundish columns,

FIG. 43.



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221. What is included under animal electricity? 222. Where is the torpedo found? On dissection, what organs does it exhibit? Describe them.

whose direction is from breast to back, or upright when the fish lies flat. Each of these columns seems to be made up of a succession of distinguishable layers piled upon one another, and separated by mucous partitions; hence it has been supposed that the electricity is produced in the same manner as in the pile of Volta, or that the entire organ is an immense bundle of piles lying side by side, conspiring altogether to make an electric charge. The number of columns in each organ depends on the size of the fish; in the one whose dimensions are stated above, 470 were counted in each; but as many as 1182 have been seen in a very large specimen. The number of layers or distinguishable partitions in a column an inch long has been found to amount to 150. A very large supply of nerves is afforded to the organs; they ramify into each column, and are distributed to the partitions—every partition receiving a nervous filament.

223. The back of the animal is positive, and the breast or belly negative, and the currents pass through the body between the breast and back. On touching either side, a shock is received; but by seizing the animal, and holding it by both sides, a much more intense shock is felt. In a second or two after receiving one shock, the charge accumulates, and discharges itself again, and thus a succession of shocks may be given, until the strength of the animal is exhausted. The electricity has to the feeling the same character as a discharge of very small Leyden jars; the intensity is small compared with machine charges, but equal to that of a very numerous voltaic pile. It is capable of magnetising iron, and of decomposing compounds; but its quantity being small, these effects are not produced to any great extent. Its use to the animal seems for defence against attacks, and as an offensive weapon generally; instead of devouring and destroying by the teeth, it launches its diminutive thunderbolts upon all creatures that approach it.

Of what are the columns made up? On what does their number depend? How are they supplied with nerves? 223. How do the currents pass? When are shocks felt?

224. A second animal endowed with electrical organs is that called the *Gymnotus Electricus*, or electrical eel, found in various parts of America. It was seen in great numbers by Humboldt in the swamps of the Orinoco in South America. Its common length is about five feet, but it often occurs much larger. Its shocks are far more formidable than the discharges of the torpedo; men, and even horses, going into the water are stunned by its touch, and are frequently drowned before they have time to recover. The following description by Humboldt of the method adopted by the Indians for catching the gymnoti, completely illustrates their character and habits. They bring a troop of wild horses, and cause them to enter a muddy pool where they are contained. " The extraordinary noise caused by the horses' hoofs makes the fish issue from the mud, and excites them to combat. These yellowish and livid eels, resembling large aquatic serpents, swim on the surface of the water, and crowd under the bellies of the horses and mules. A contest between animals of so different an organisation, furnishes a very striking spectacle. The Indians, provided with harpoons and long slender reeds, surrounded the pool closely; and some climb upon the trees, the branches of which extend horizontally over the surface of the water. By their wild cries, and the length of their reeds, they prevent the horses from running away, and reaching the banks of the pool. The eels, stunned by the noise, defend themselves by the repeated discharge of their electrical batteries. During a long time they seem to prove victorious. Several horses sink beneath the violence of the invisible strokes which they receive from all sides on organs the most essential to life, and, stunned by the force and frequency of the shocks, disappear under the water. Others, panting, with mane erect, and haggard eyes expressing anguish, raise themselves, and endeavour to flee from the storm by which they are overtaken. They are driven back by the Indians into the middle of the water; but a

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224. Where is the electrical eel found? What is its usual length? What means do the Indians employ to catch them? How are the eels excited, and what is their appearance?

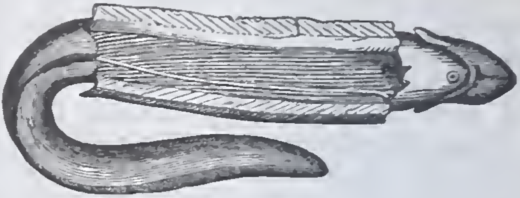
small number succeed in eluding the active vigilance of the fishermen. These regain the shores, stumbling at every step, and stretch themselves on the sand, exhausted with fatigue, and their limbs benumbed by the electric shocks of the gymnoti. In less than five minutes two horses were drowned. The eel being about five feet long, and pressing itself against the belly of the horses, makes a discharge along the whole extent of its electrical organ. The horses are drowned, from the impossibility of rising amid the prolonged struggle between the other horses and the eels. By degrees the impetuosity of this unequal combat diminished, and the wearied gymnoti dispersed. They require a long rest and abundant nourishment to repair what they have lost of galvanic force. The mules and horses appear less frightened ; their manes are no longer bristled, and their eyes express less dread. The gymnoti approach timidly the edge of the marsh, where they are taken by means of small harpoons fastened to long cords. When the cords are very dry, the Indians feel no shock in raising the fish into the air. In a few minutes our party obtained five large eels, the greater number of which were but slightly wounded."

225. In the gymnotus the structure of the electrical organ is not the same as in the torpedo. It occupies nearly four-fifths of the length of the animal, and is formed of thin plates lying in the direction of its length (see fig.) ; so that one end of the pile is at the tail and the other end near the head. Hence its shocks are most powerful when it brings both head and tail into contact with another animal There are two pairs of organs, and their total bulk amounts to about one-third of the whole body of the fish. Two rows of small yellow spots are seen running along the back from head to tail, and every spot contains an opening which gives forth a mucous matter, which covers the skin, and is found to be a remarkably good conductor of electricity.

What do the eels require to supply their exhaustion? What number of them were taken? Where, and how? 225. How is the electric organ formed? When are its shocks most powerful?

226. In the rivers of Africa—in the Senegal, the Niger, and the Nile—is found a third species of electrical fish, called the *Silurus Electricus.* It is about twenty inches long.

FIG. 44.



It is caught and eaten by the Egyptians. Its electrical organs lie beneath the skin, all round the animal, and are less complicated than in the torpedo and gymnotus. Various other electrical fishes have been met with.

227. In all these animals the electrical apparatus is an addition to the ordinary vital organs, and its action is quite independent of them. It is not involved in the operations of digestion, circulation, or movement; but, like all other organs, it is supplied with nerves from the brain. It seems to be under the control of the animal to about the same degree as its moving apparatus. Although the structure of the organ is somewhat similar to a voltaic arrangement, and the shock the same as would be felt from a battery made up of several hundreds of small plates in a weak solution, it is not completely proved that it operates on the principle of the pile.

228. Apart from the possession of special apparatus, the operations of the animal body are such as to evolve electricity in many ways. The chemical process of digestion and respiration—the constant passage of heat to and fro—the mechanical movements—may all generate electricity. The most common case of the appearance of excitement in the human subject is, when the clothes are stripped from the skin in a very dry air. When silk stockings are

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226. Where is the Silurus Electricus found? What is its length? Where do its electrical organs lie? 227. What relation do the electrical organs bear to the vital organs and brain?

taken off, they sometimes cause a crackling noise, accompanied with sparks, which may be distinctly seen in the dark. If the skin and clothes are perfectly dry, this effect would probably be constant, as it is a mere effect of the friction. In very dry climates, where the atmosphere is so deficient in moisture as to keep all surfaces in a dry state, the observation is very familiar; it is also observed in rooms heated by stoves, which have the same excessive desiccating tendency.

229. Of the entire amount of electricity produced by the interior processes of the human body, only a small portion can appear in a free state on the surface; the greater part must be consumed again or discharged in other operations. In as far as the skin acquires a charge, its general character is found to be positive; but the amount differs very much in different individuals, and in the same individual at different times. A development of positive electricity seems to be identified with the health, vigor, and freshness of the body; for it diminishes, and is changed into negative, by great exertions and fatigue, by lassitude and cold. A sudden fit of violent exertion will in an instant convert the positive charge into a negative one. We may therefore suppose that the operations of nutrition are constantly generating positive electricity, while exertion and the wasting operations generate negative; that the nourishing processes are like the cells of the voltaic pile, where, by the consumption and chemical transformation of material, the excitement is produced; and the wasting operations like the place of action in the circuit, where the excitement is expended in producing effects of heat, decomposition, or moving power. Liebig has found that the juices of the flesh or muscle are constantly acid, while the blood in the arteries and veins circulating through the flesh is alkaline. But an acid and alkali, with a membrane between them, are capable of causing a current, the acid being positive, and the alkali negative; so that the blood

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228. How may electricity be generated in animals? What is caused by dryness and friction? 229. When is the electricity of the skin positive? When negative? What is shown of the flesh and blood?

would from this cause have a negative charge, and the flesh a positive charge.

230. The effects of electricity on the animal system are as yet very little understood. Electric shocks have been applied as remedies for diseases, and have often been productive of good. The chief disorder where they are found valuable is the case of paralysed limbs. By passing a long-continued series of discharges through a torpid arm or leg, it has often been restored to vigor. For this purpose the ordinary friction machine has been commonly employed; but it is supposed that the magneto-electric machine may prove a much more powerful stimulant. Relief has been given also to patients suffering from tic.

231. It may be surmised, that if the human body in its ordinary healthy state contains a surplus of positive electricity, and if the earth is in general negative, there is a propriety in keeping some insulating substance between the feet and the naked ground. We may thus assign an additional reason for the disagreeable and unhealthy effects of damp feet; for besides cooling down the system, the moisture will conduct away the body's free electricity to the earth, and with this a certain portion of the vigor of the frame. On the same principle fogs, which are commonly negative, by enveloping the person, must take away its positive electricity; and their unpleasant action may in some measure be owing to this cause. The sudden and frequent changes of the state of the atmosphere before and during a thunder storm, are very distressing to many people. On the whole, therefore, it may be safely affirmed that human comfort is affected to a very considerable degree by the electrical phenomena of nature.

232. The actions of vegetable life are such as cannot fail to be attended with the evolution of electricity. The great range of chemical decompositions and combinations which go on during the growth of plants, is a sufficient cause of an abundant electrical excitement. Observations

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230. In what diseases have electric shocks been useful? What machine is used? 231. What reason may be given why damp feet are unhealthy? Why fogs?

and experiments have shown that this actually occurs; there is a constant circulation of electricity of feeble tension in living vegetables. But although there is too little insulation or resistance by bad conductors, to cause this electricity to assume a high intensity, so as to give shocks or sparks, the quantity of it may be very great, and it may contribute in some essential ways to the maintenance of the organic life. If we consider that electrical currents are the means of conveying chemical force from one place to another, we may easily imagine that this conveyance is sometimes necessary to the growth of vegetables. A certain power evolved at the roots in the earth, or at the leaves in the air, may be required in other parts of the plant. The decomposition of the seed may give birth to an electric current which effects important changes in the expanding germ. It has been found that by causing the seed to assume an electric state opposite to what it naturally assumes, its development is retarded or checked. Hence, on the other hand, it is perfectly credible that the growth of plants may be very much quickened by communicating electricity to them by artificial methods. Minute and long-continued observation, however, is yet required to enable us to state with accuracy the precise functions of electrical excitement in organised bodies.

ANIMAL MAGNETISM.

233. Besides the well-known effects on the human system of electrical shocks, either from friction machines, from voltaic piles, or from magneto-electrical apparatus, a totally different kind of influence has for some time back been asserted to arise from the action of magnets. This influence is said to be felt most intensely by persons suffering under disease of the nerves, and it is capable of producing extraordinary states of body and mind. There is great difficulty in getting the exact truth contained in observations about the human feelings, especially when

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232. What conjectures are made with regard to the growth of vegetables? How may their development be checked or increased?
233. By whom is another magnetic influence said to be most felt?

men's minds are excited by the sentiment of the marvellous. But the knowledge now possessed on the whole subject of electricity, coupled with some experiments of an accurate kind lately performed, enable us to make a few statements on this subject which will not appear inconsistent with the rigor of a scientific work.

234. In the first place, it is an inevitable consequence of Faraday's discovery of magneto-electricity, that a magnet pointed to the back, the arm, the leg, or any other part of the human body containing a considerable nerve, and moved along in the course of the nerve, must produce, by magneto-electric induction a current of electricity. The effect will be nearly the very same as a weak current from the magneto-electric machine. The influence of a magnet thus passed up and down over the body will be a perceptible thing; there will be imparted a current in one direction while it is moved one way, and an opposite current when it is moved the other way, and all the effects will arise which are caused by electric currents in the first place, and by the frequent reversing of them in the second place. Any one may confirm by their own experience the truth of this necessary inference from the laws of magnetic induction. In the generality of people very weak magnets may produce an indubitable sensation; and by using magnets of a higher power, the effect will be so decided as to felt by every one.

235. But it is now asserted by Baron Reichenbach, (and the assertion is supported by experiments of a trustworthy character,) that magnets have on certain very nervous persons an influence of a kind totally distinct from the above. The magneto-electric induction is produced only so long as the magnet is kept in motion, this being the essential condition of the induction. If a person pretend to feel any action from a magnet while both he and it are at rest, it cannot be from an electric current, or from the proper electric influence of the magnet. But, according to

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234. What will a magnet moving along a nerve produce? When will the sensation caused be perceptible? 235. What is stated that some persons perceive on magnets? Is this light real? Why?

Reichenbach, there are some individuals who see on a magnet in the dark aurora flames streaming out from the poles and along the edges of the bar. It has been proved that this light is a real existence, and not a mere fancy of diseased nerves, by its acting on Daguerreotype plates like ordinary solar light; so that the inference is, that magnets are actually luminous, but with a degree of luminosity so very feeble, that even in pitch dark it cannot affect ordinary eyes.

236. Besides the luminous phenomena of a magnet, it has been found able to act upon the system of sensitive patients in various ways. The hand of the patient is said to follow it by a mysterious attraction; and when the arm or any other part is streaked with it, a sensation is produced which in one direction feels cool and in the other warm; or opposite poles drawn in the same way, will cause opposite sensations. Moreover, by streaking any object, such as a glass of water, the patient is aware of a change having come over it. By the action of magnets, intense pleasure or violent uneasiness may be communicated to susceptible persons; and this effect arises also from the magnetism of the earth; for such persons feel a degree of suffering amounting to illness when they lie in bed with their heads to the west and feet to the east; whereas they enjoy perfect repose in the direction of the magnetic meridian —the head being to the north.

237. But to show that this influence is not the result of the ordinary magnetic property of loadstone or the electro-magnet, it is alleged to rise from *crystals* also, which have no magnetic action in general. A crystal presents all the appearances—of illuminated poles, attraction for the hand, and cool and warm sensations, according to the pole used. It follows, therefore, that the power of a magnet over highly sensitive people is something additional to its recognised properties, and common to it with crystals.

238. A recent discovery of Faraday gives considerable

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236. How is a magnet said to act on sensitive persons? What position disturbs their rest? 237. What is stated of crystals? What follows from this?

support to the assertion of a common influence in magnets and in crystals; and although it does not actually prove the statements of Reichenbach, it serves to take off the air of incredibility that might otherwise surround them. So explicit are Faraday's observations, that they have led him to assert the existence of a *new magnetic condition*, or a *new magnetic force*—that is to say, a power possessed by magnets perfectly distinct from their attraction for iron. Moreover, this force is shown by its action on *crystals*.

239. When a ray of light is reflected at a certain angle from a mirror, it is polarised, or acquires such a property that a second reflection in a particular way will extinguish it. Light is likewise polarised by passing through certain transparent bodies; and the effect always is, that after the second action, the ray appears only in one position of the second substance; in other positions it is extinguished. Faraday employed a polarising apparatus, consisting of a mirror, to give the first influence, and a transparent body for the second, so that after a reflection and a transmission the light was reduced to the state of partial appearance. In the course of the ray from the mirror to the *eye-piece*, (as the second polarising substance is called,) he placed a crystal so that the ray must pass through it. This crystal of itself has no polarising influence; but if it is arranged so as to lie between the poles of a powerful electro-magnet when the magnet is rendered active, the crystal instantly becomes charged with an influence which is made known by a change in the appearance of the polarised ray after it has passed through the eye-piece. If, before the magnetism is set on, the eye-piece is so arranged that the polarised ray is visible, after completing the circuit the ray is made *invisible*. It is not, however, destroyed or entirely extinguished; for if the eye-piece is turned round somewhat to one side, it reappears. So if the eye-piece is first placed in the position

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238. What does Faraday assert to exist? 239. When is light polarised? What is meant by this term? What was Faraday's polarising apparatus? What is the eye-piece? If the crystal lie between the poles of a magnet, what effect is produced? When is the ray said to rotate?

in which the polarised ray is extinguished, the action of the magnetism on the intervening crystal will bring it into view; and the eye-piece must again be rotated, in order to cause the same extinction as before the magnetism was made active. Hence the power of a magnetised crystal is expressed by saying that it makes a polarised ray to *rotate;* for the ray's positions of appearance and disappearance are so far changed, that the eye-piece must be revolved to one side or another to bring them out.

240. There is thus an influence possessed by magnets over the atoms of crystals, whereby these give a bias different from their ordinary action to all rays of light that pass through them. Something common must attach to one constituent of magnetic force and one constituent of crystalline force, in order that the one may overpower or modify the other; for forces which act and react on each other must be similar in kind. The crystal, while under the magnetic influence, acquires no attraction for iron, nor any other feature of common magnetism; and therefore it is alleged with justice that a power altogether new and different is hereby made manifest. Thus both the results of Faraday, and the observations of Reichenbach, point to a power over and above common electricity, although of the true polar character; for Faraday found that the reversal of the poles of the magnet reversed the direction of the rotated ray; in one case the ray had to be sought by revolving the eye-piece to the right; and with reversed poles it reappeared by revolving the eye-piece to the left.

241. But Reichenbach found his new force in many other quarters besides magnets and crystals. It arises from the sun's rays, the moon's rays, from heat without light, from friction, from chemical action, and from the human hand; and it seems also present in some degree in the material world at large; so that to the sensitive patient all nature is illuminated in the deepest gloom of midnight.

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240. What is inferred from the influence of magnets over crystals? Why must a power exist in magnets different from their attraction for iron? What effect had the reversal of the poles of the magnet on the rotated ray?

A faint luminous haze of varied colors appears all over the objects of a room, the persons, and especially the hands of human beings, and over dead bodies and recently occupied graves. On the whole, it is impossible not to be struck with the connection which the new magnetic condition has with light in the very dissimilar experiments of Reichenbach and Faraday.

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241. Where, besides in magnets and crystals, was the new force observed? What objects appeared luminous to the patient in the dark?

SUPPLEMENT.

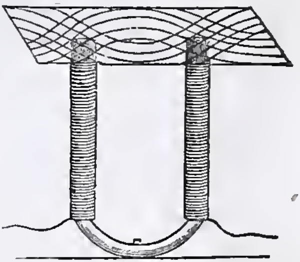
Atoms.—M. Laurent, in his memoir, gives the following propositions:—"In all azotized substances, represented by 4 volumes, the sum of the atoms of hydrogen and azote is always a multiple of 4."—"In all organic substances, the sum of the atoms of the hydrogen, azote, phosphorous, arsenic, the metals, and the halogen bodies, ought to be divisible by 2."—(V. Am. Jour. Sci. & Arts, Sept., 1847.)

Butyro-Acetic and Metacetonic Acids, the identity of, has been ascertained by MM. Dumas, Leblanc, and Malaguti.

Carbonic Acid.—By the united aid of cold and pressure, Faraday has succeeded in reducing 15 æriform bodies to the liquid or solid state. Carbonic acid, when condensed, becomes a clear, transparent, crystalline solid, at temperatures below —71°; and if it be moistened with ether *in vacuo*, the greatest cold yet observed is produced. Thilorier has contrived apparatus for condensing it on a large scale.

Catalysis—a term proposed by Berzelius to express the peculiar power, possessed by some bodies, of aiding chemical changes by their presence only.

Crystallization—influenced and promoted by magnetism. When nitrate of mercury on a glass plate is placed over the poles of an electro-magnet, as in the figure, crystallization takes place in the curved lines here shown. By substituting a plate of copper for the glass, it is curiously etched in the magnetic curves by the acid of the silver salt.—*Silliman, Jr.*



Diamagnetism.—There is a class of bodies which are repulsed by the two poles of a magnet. Faraday found that this repulsion is produced upon almost all bodies not attracted; and also, that bodies having unequal dimensions of length and breadth, when thus repelled under the influence of an electro-magnet, took a position perpendicular to that which an attractive body would take under the same circumstances: this property he calls *diamagnetism.* The experiments of Œrsted upon the influence of heat on diamagnetic bodies, show that some attracting diamagnetic bodies pass into the class of repellant diamagnetic, by an increase of temperature. From the experiments of Plücker, we learn that, a crystal being neither transparent nor showing any trace of its crystalline structure, we may by means of a magnet find the optical axes.—(V. Am. Jour. Sci. & Arts, Mar., 1849; and Ann. de Ch. et de Phys., Dec., 1848; and Athen., No. 1086.)

Dimorphism—the property of crystallizing in two distinct forms not derivable from one another. Zinc is dimorphous, as also tin. Palladium and iridium are isodimorphous.

Electricity.—Dr. Hare objects to the theories of Franklin, Du Fay, and Ampère, and explains electrical phenomena by statical or undulatory polarization. In the summary to his paper, he says: "A charge of frictional electricity is not due to any accumulation nor to any deficiency either of one or two fluids, but to the opposite polarities induced in imponderable ethereal matter existing throughout space however otherwise void, and likewise condensed more or less within ponderable bodies, so as to enter into combination with their particles, forming atoms which may be designated as ethereo-ponderable." Dr. Kane gives the general order of the conducting powers of bodies as follows, commencing with the best insulators:

Dry air,
Shell lac,
Resins,
Oil of Turpentine,
Sulphur,
Glass,
Spermaceti,
Damp organic bodies,
Damp air,
Water,
Strong acids,
Fused saline bodies,
Charcoal,
Metals.

A body becomes heated in proportion to the resistance offered to the motion of the electricity; therefore the rise of temperature is inversely proportional to the conducting power. Harris found that, with

	Heat evolved.	Conducting Power.
Silver	6	120
Copper	6	120
Gold	9	80
Zinc	18	40
Platinum	30	24
Iron	30	24
Tin	36	20
Lead	72	12

ELECTRO-MAGNETISM.—M. Ch. Mène has constructed an electro-magnetic balance for measuring the intensity of currents, which consists of a horse-shoe of soft iron wound a certain number of times with an insulated wire; the armature is attached to a counterbalanced scale-pan. The intensity is directly measured by the magnetic force developed. The weight supported, divided by the number of turns, represents the influence of one turn of the wire. Electro-magnetism has recently been applied with success by Dr. Page, to the propulsion of machinery.

ELEMENTS AND THEIR COMPOUNDS.—Most of the following substances have been recently discovered, and are not found in the preceding pages:—1. *Absinthiin* is the bitter principle of wormwood. 2. *Acetene* is a volatile oily liquid, C^4H_6 3. *Acctone* is a volatile liquid, of sp. gr. ·793, and has a pungent odor. 4. *Aconitic acid* is formed by heating citric acid; composition, $C^{12}H^6O^{12}$. 5. *Aconitine* is an acrid poison. 6. *Acroleine* is made by heating glycerine; formula, $C^6H^4O^2$. 7. *Adipic acid* is composed of $C^{12}H^{10}O^8$. 8. *Anamirtic acid*, obtained from the berries of the Anamirta coculus, is $C^{36}H^{36}O^4$. 9. *Antimonic acid* (SbO^5) is formed by digesting antimony in nitric acid. 10. *Antimonius acid* is a gray powder, of S^6O^4. 11. *Arsenic acid* is formed by adding nitric acid to a solution of white arsenic; its formula, AsO^5. 12. *Arsenious acid*, called rat's bane, is AsO^3. 13. *Powder of Algaroth* is a mixture of oxide and chloride of antimony. 14. *Alizarine*, the coloring principle of madder, is volatile. 15. *Alcargene*, a crystallized compound, is $C^4H^5AsO^4$. 16. *Alcarsine* is a volatile liquid, of sp.gr. 1·462; boils at 300°; formula, $C^8H^{12}As^2O^2$. 17. *Allantoine* exists in the amnistic fluid of the cow; formula, $C^8H^6N^4O^6$. 18. *Alloxan* is formed by adding uric acid to nitric; formula, $C^8H^4N_2O^{10}$. 19. *Alloxantine* is formed by the action of deoxydizing agents on alloxan; formula, $C^{16}H^{10}N^4O^{20}$. 20. *Amarine* or *Benzeline* is an alkaloid composed of $C^{42}H^{18}N^2$. 21. *Ammelide* is $C^6H^4N^4O_4$. 22. *Ammeline* is $C^6H^5N^5O^2$. 23. *Acetate of Ammonia* is the spirit of Mindereus, ($C^4H^4O^4+NH^3$). 24, 25. *Bin-iodized* and *tri-chlorinized ammonia* are produced by the reaction of ammonia with iodine and chlorine. 26. *Hydro-sulphuret of ammonia* is a very useful compound, consisting of NH^1S+HS. 27. *Oxalate of ammonia* is much used in analysis; formula, $C^4H^2O^8\,2NH^3$. 28, 29, 30. *Opianate, hemi-pinate*, and *succinate of ammonia*, are composed of C, H, N, and O. 31. *Ammonium* is a supposed metallic radical, (NH^4). 32. *Sulphate of oxide of ammonium* is a powerful fertilizer, (NH^4O, SO^3+HO). 33. *Carbonates of oxide of ammonium*, of these, the white sal-volatile of the shops is one. 34. *Nitrate of oxide of ammonium* (NH^4O,NO^5), resembles nitre. 35. *Sulphocyanid of ammonium* is obtained from prussic acid. 36. *Amygdaline* ($C^{40}H^{27}NO^{22}$), is contained in bitter almonds and peach kernels. 37. *Amylether* or *Amylic ether* ($C^{10}H^{11}O$), appears to be formed by the distillation of sulphamylic acid. 38. *Amylol* or *Amylic alcohol* resembles alcohol and wood-spirit; sp.gr.·818; boils at 269°. 39. *Anilene* ($C^{12}H^7N$), is a colorless, oily liquid, boiling at 328°. 40. *Terchloride of antimony* ($SbCl^3$) is used in medicine. 41. *Bromide of antimony* is volatile. 42. *Tersulphuret of antimony* (SbS^3) is a native mineral. 43. *Pentasulphuret of antimony* (SbS_5) is known by the name of sulphur auratum, or, golden sulphur of antimony. 44. *Aricine* is an alkaloid observed in cinchona. 45. *Chloride of arsenic* ($AsCl^3$) is a fuming volatile liquid. 46. *Sulphurets of arsenic* are known by the names, orpiment and realgar. 47. *Aspartic acid* ($C^8H^7NO^8$) is concrete or crystallized, and obtained from asparagus. 48. *Arsine* (C^4H^5As) is an alkaloid. 49. *Asparagine* ($C^8H^6N^2O^6$) is the amide of aspartic acid. 50. *Asafœtida* is the concrete juice of the Ferula assafœtida. Its oil contains sulphur. 51. *Atropine* is an alkaloid obtained from Atropa belladonna. 52. *Acetule* is a compound radical; equiv., 27.48; symb. C^4H^3, or Ac. 53. *Ambreine* is the chief constituent of ambergris. 54. *Ambergris* is a solid, ash-colored, inflammable substance, remarkably light, and is a morbid secretion into the intestines of a species of Physeter. 55. *Ammidogen* is a basifying and basic principle, composed of H^2N. 56. *Ammelide*, a compound radical, of $C^{12}N^9H^9O^6$. 57. *Amygdine* is crystalline, and obtained from the bitter almond. 58. *Archil*, a red dye from the Lichen rocella.

59. *Barium* is a silver-white malleable metal; equiv., 68.55. 60. *Chloride of Barium* ($BaCl+2HO$) is a valuable reagent. 61. *Nitrate of Baryta* (BaO, NO^5O), a white salt. 62. *Carbonate of Baryta* (BaO, CO^2) is the chief source of the various compounds of baryta. 63. *Allophanate of Baryta*, a salt of *allophanic acid* which is a product of the action of cyanic acid upon alcohol and aldehyde. 64. *Sulphate of Baryta* (BaO, SO^3) or *heavy spar*, is a mineral. 65. *Benzamide* ($C^{14}H^7NO^2+HCl$) is obtained from benzoilol. 66. *Benzoine* ($C^{28}H^{12}O^4$) is white and crystalline, polymeric of the oil of almonds. 67. *Benzene* or *Benzole* ($2CO^2+C^{12}H^6$) is a colorless, fragrant, liquid, obtained from benzoic acid. 68. *Benzoilol* is the essential oil of bitter almonds. 69. *Sulphureted Benzoilol* is $C^{14}H^6S^2$. 70. *Chlorinized Benzoilol* ($C^{14}H^5ClO^2$) is a colorless liquid. 71. *Nitrate of Bismuth* is BiO,NO^5+3Ho. 72, 73, 74, 75. *Boron*, its compounds are, the acid, chloride, fluoride, and sulphuret. 76. *Brucine*, an organic base and poison. 77. *Butyrine*, a glyceride, to which butter owes its flavor. 78, 79. *Butyrone* and *Butyral*, afforded when butyrate of lime is distilled. 80. *Benzoic acid* ($C^{14}H^6O^4$) occurs in the form like silky crystals. 81. *Bromic acid* (BrO^5) is similar to chloric. 82. *Butyric acid* ($C^8H^8O^4$) is a limpid, colorless liquid; sp. gr. .963. 83. *Bassorin* is an ingredient of gum tragacanth. 84, 85. *Cadmium*, a metal, fuses at 442°; density, 8·65. Its *oxide* (CdO) is a bronze powder. 86. *Caffeine* is white and

bitter, and obtained from coffee. 87. *Chloride of Calcium* ($CaCl$) is a white crystalline solid. 88. *Fluoride of Calcium* (CaF) is the mineral fluor spar. 89. *Camphene* is pure oil of turpentine. 90. *Capsicine* is an organic base, to which the pungency of Cayenne pepper is due. 91. *Carthamine* is the red coloring matter of carthamus. 92, 93, 94, 95. *Carbon*, of this, there is a chloride, perchloride, dichloride, and sulphuret. 96. *Caseine* constitutes the curd of milk. 97. *Cellulose* ($C^{12}H^{10}O^{10}$) is woody fibre. 98. *Cerium* is a rare metal. 99. *Cetene*, or spermaceti, is the aldehyde of ethal. 100. *Cinnamol* is the oil of cinnamon. 101. *Cinnamic acid* is $C^{16}H^{9}O^{4}$. 102. *Cinchonine*, an alkaloid of cinchona. 103. *Chloranile* ($C^{12}Cl^{4}O^{4}$) is the product of the action of chlorine upon isatine. 104, 105. *Chloranilene* ($C^{12}(H^{6}Cl)N$) and *Bichloranilene*, are crystalline solids, and act as bases. 106. *Chlorarsine* is a colorless liquid. 107, 108. *Chlorisatine* and *Bi-*, are yielded by the action of chlorine upon indigo. 109. *Chloroform* or *Tri-chlorinized Formene*, ($C^{2}HCl^{3}$) is formed when alcohol is distilled with 2 or 3 parts of chloride of lime dissolved in 20 parts of water; being a heavy oily liquid, boiling at 141°, and has sp.gr. of 1·48. Dissolved in alcohol, it forms chloric ether, and is used in medicine. 110. *Cholesterine*, a crystalline fat in bile. 111. *Chondrine*, the substance of cartilage. 112. *Chromium*, a metal resembling cast-iron. It forms 5 compounds with oxygen. 113. *Chromic acid* (CrO^{3}) forms ruby red crystals. 114. *Codeine* ($C^{36}H^{21}NO^{6}$) occurs with morphine. 115. *Columbium* or *Tantalum*, is a rare metal; it forms two oxides. 116. *Conine* ($C^{16}H^{16}N$) is an oily liquid and alkaloid. 117. *Acetate of Copper* ($C^{4}H^{3}C^{4}O$) forms green crystals 118, 119. *Copper* forms two oxides—CuO and $Cu^{2}O$. 120. *Cotarnine* ($C^{26}H^{13}NO^{6}$) an alkaloid. 121, 122. *Cyanic acid* ($C^{2}HNO^{2}$) when kept for some time changes into a white insoluble mass, called *cyamelide*. 123, 124, 125. *Chloride*, *Iodide*, and *Bromide of Cyanogen*, are crystalline, volatile, poisonous. 126. *Cyanoxsulphide*, a yellow precipitate. 127, 128, 129. *Capric*, *Caproic*, and *Caprylic acids*, are volatile, and derived from fat. 130. *Carbazotic*, *Nitrophenisic*, *Nitropicric*, or, *Picric*, *acid*, or *Tri-nitrophenol*, is the product of the action of nitric acid on phenol. 131. *Carbovinic acid* ($C^{10}H^{10}O^{6}$) is a colorless liquid. 132. *Cerebric acid* is obtained from the brain. 133. *Chloroacetic acid* ($C^{4}Cl^{3}HO^{4}$) resembles acetic. 134. *Chlorous acid* (ClO^{4}), a deep yellow, explosive gas. 135. *Choleic acid*, a fatty acid in the bile. 136, 137. *Citraconic acid* is an oily fluid; when heated, it forms *citraconide*. 138. *Cocinic acid* is from cocoa-nut oil. 139. *Cuminic acid* is obtained from the oil of cumin. 140. *Cyanuric acid* is polymeric of the cyanic. 141. *Capnomar* is analogous to creosote. 142. *Caramel* is formed when sugar is heated to 420°. 143. *Cathartin*, the active principle of senna. 144. *Cytisin* is a bitter purgative principle. 145. *Cerine*, a principle of bees-wax.

146. *Cholesterine*, obtained from the bile 147, 148. *Corydalia* and *Cynopia*, vegetable alkalies. 149. *Chloroginic acid* is obtained from coffee. 150. *Cuminamid* ($C^{20}H^{13}NO^2$), formed by the decomposition of cuminate of ammonia. 151. *Cumonitrile* ($C^{20}H^{11}N$) is a light oil; sp. gr. 0·765; boiling point, 462°. 152, 153, 154. *Glyco-cholic*, *Cholalic*, and *Choloidinic*, *acids* are found in oxgall.

155. *Dextrine* is obtained from starch. 156. *Diastase* is a modified form of gluten. 157. *Didymium*, a metal, associated with cerium. 158. *Diaturic acid*, composed of $C^8H^4N^2O^8$. 159. *Delphia*, a vegetable alkali. 160. *Dyslisin* ($C^{48}H^{36}O^6$) is found in oxgall.

161. *Elaldehyde* ($C^{12}H^{12}O^6$) is a dense oily fluid. 162. *Emetine* is the emetic principle of ipecacuana 163. *Emulsine* or *Synaptase*, an albuminous matter. 164. *Ethal* ($C^{32}H^{34}O^2$) is obtained by the action of the hydrate of potash upon spermaceti. 165. *Acetic ether* ($C^8H^8O^4$) is obtained by distilling 5 parts of acetate of soda, 8 of sulphuric acid, and 3 of alcohol. 166. *Acetic amylic ether*, composed of $C^{14}H^{14}O^4$. 167. *Hydrochloric amylic ether* is composed of $C^{10}H^{11}Cl$. 168, 169. *Boracic ethers* are formed by the action of chloride of boron on alcohol. 170. *Butyric ether* ($C^{12}H^{12}O^4$) is used to flavor spirits. 171. *Hydrobromic ether* (C^4H_5Br) resembles hydrochloric ether. 172. *Hydriodic ether* (C^4H^5I) sp. gr. 1·92. 173. *Hydrochloric ether* (C^4H^5Cl) ·873; colorless, volatile liquid, with a pungent aromatic odor; boils at 52°. 174. *Nitric* or *Hyponitric ether* or *nitric acetene* ($C^4H^5NO^4$). a pale yellow fluid, of the odor of apples; sp. gr. ·947. 175. *Wood* or *Methylic ether*, or *mether*, composed of C^2H^3O. 176. *Oxalic ether* is $C^{12}H^{10}O^8$. 177. *Perchloric ether* (C^4HCl^6) is extremely explosive. 178, 179. *Silicic ethers* are formed by the reaction of chloride of silicon on alcohol. 180. *Sulphureted ether* (C^4H^5S), a colorless, volatile liquid, with a garlic odor. 181. *Elaidic acid* is formed from, and resembles, oleic acid. 182. *Enanthylic acid* ($C^{14}H^{14}O^4$) is volatile and oily. 183. *Ethalic acid* is formed from ethal. 184. *Equisetic acid* is formed from the equisetum. 185. *Ethule* (C^4H^5), a compound radical. 186. *Eupione* is analogous to creosote. 187. *Cyanide of Ethyle*, prepared by distilling together sulphovinate of potash and cyanide of potassium. 188. *Ethyle*, a hypothetical radical, existing in ether.

189. *Ferridcyanide of potassium* is the red prussiate of potash. 190. *Ferrocyanide*, a compound of the protocyanide of iron with some other cyanide. 191. *Ferric acid* corresponds to manganic acid. 192. *Ferridcyanic acid* is obtained by the decomposition of ferridcyanide of lead by sulphuric acid. 193. *Ferrocyanic acid* is a white crystalline substance. 194. *Fluosilicic acid* is the fluoride of silicon. 195. *Formic acid* occurrs as a secretion of the red ant. 196. *Fulminic acid* forms explosive salts. 197. *Fumaric acid*, found in Iceland moss.

198. *Galleide*, a reddish brown crystalline powder—being gal-

lic acid minus 2 equiv. of water. 199. *Geine*, *humic* or *ulmic*, *acid*, *humus*, and *ulmine*, are names given to the products of the decomposition of animal and vegetable bodies. 200. *Glucinum*, a metal, found in beryl and other gems. 201. *Glucose* is grape sugar. 202. *Glycerides* are obtained from fatty matter. 203. *Glycocoll*, obtained from urine, and called sugar of gelatine. 204. *Gun-cotton* or *Pyroxyline*, or *Schiesswolle* ($C^{24}H^{10}(NHO^4)^5O^{20}$,) is thus prepared, according to *Silliman, Jr.*: 100 grs. of clean cotton are immersed for 5 minutes in a mixture of an ounce and a half of nitric acid of sp. gr. 1·45 to 1·5, with the same measure of strong sulphuric acid ; it is then removed, carefully washed in cold water from every trace of acid, and dried at a temperature which should not exceed 120°. It inflames by a very gentle heat; and its combustion is instantaneous, 100 grs. affording, according to *Parrett* and *Teschemacher*, 64·550 grs. of mixed gases, besides water, carbon, and oxalic acid. Its power in propelling balls is about 8 times greater than that of gunpowder. It has been applied, with apparent success, to the movement of machinery. Dissolved in ether, constituting collodion, it has become an important material for dressing incised wounds, and may be used for the tooth-ache. 205. *Gutta Percha* (C87·8, H12.2) exudes from a genus of the Sapoteæ, and much resembles caoutchouc. It is of a dirty white color and a greasy feel, with a peculiar leathery smell. It becomes soft and plastic when immersed in water above 150°, sp. gr. 0·9791. 206. *Gentianin* is procured in acicular crystals from gentian. 207. *Garancine*, an extract of madder.

208. *Helicine*, procured from the willow. 209. *Hematine*, a red coloring principle in blood. 210. *Hematoxyline* is obtained from log-wood. 211. *Hydrobenzamide*, obtained from benzoilol. 212. *Hydrosalimide*, procured from oil of spirea ulmaria. 213. *Arseniureted hydrogen* is the most deadly poison known. 214. *Boruret of hydrogen*, a combustible gas. 215. *Tellureted hydrogen* resembles the sulphureted. 216. *Phosphureted hydrogen* spontaneously inflames. It is prepared by heating slaked quicklime, water, and phospurus in a retort. 217. *Hippuric acid* ($C^8H^9NO^6$) exists in wine. 218. *Hydriodic acid* is formed by acting on iodine and water with phosphorus. 219. *Hydrobromic acid* is prepared by the reaction of moist phosphorus on bromine. 220. *Hydroselenic acid* resembles sulphureted hydrogen. 221. *Hydrofluoboric acid* is formed from fluorid of boron. 222. *Hyperiodic acid*, composed of IO^7. 223. *Hyponitrous acid* (NO^3.) is a thin mobile fluid. 224. *Hypophosphorous acid* (PO) is little known. 225. *Hircine*, an animal substance. 226. *Hemipinic acid*, $C^{10}H^{10}O^6$.

227. *Indigogene* exists in indigo. 228. *Iodiform* (C^2HI^4) is tri-iodized formene. 229. *Iridium*, a metal, associated with platinum. 230. *Carbonate of iron* occurs naturally as spathic iron ore.

231. *Lactate of iron* is used in medicine. 232. *Isatine*, found in indigo. 233. *Isatyde* ($C^{16}H^{6}NO^{4}$), *ibidem.* 234. *Iodic acid*, IO^{5}. 235. *Isatinic acid* exists in indigo. 236, 237. *Ilmenium*, a metal, discovered by *Hermann*. *Ilmenic acid* is its oxide.

238. *Kakodyle*, a colorless, poisonous liquid. 239. *Kyanol*, an organic alkaloid, in coal-tar. 240. *Kinic acid*, a bibasic acid from cinchona. 241. *Lactide*, from lactic acid, is white and crystalline. 242. *Lactine* is the sugar of milk. 243. *Lantanum*, a metal, associated with cerium. 244. *Chromate of lead* is chrome yellow. 245. *Sulphuret of lead* is the native galena. 246. *Lecanorine*, a colorless principle in the lichens. 247. *Legumine* is found in the seeds of beans and peas. 248. *Leiocome* is British gum. 249. *Letheon*, an ether; the inhalation of, to produce insensibility during surgical operations, suggested by *Dr. C. S. Jackson.* 250. *Leukol*, an alkaloid found in coal tar. 251. *Lignite*, a product of the decomposition of wood. 252. *Lactate of lime* is $C^{6}H^{5}CaO^{6}$. 253. *Butyrate of lime*, formed when sugar, chalk, and curd, are kept at about 90°. 254. *Oxalate of lime* is secreted by a large number of plants. 255. *Luteoline*, a coloring principle. 256. *Lactic acid* is produced by the fermentation of sugar and cheese curd. 257, 258. *Lauric acid* is afforded when *laurine*, a glyceride from the laurel, is saponified. 259. *Lophia* is $C^{23}H^{16}N^{2}$.

260. *Carbonate of magnesia* is found native. 261. *Magnesium* is a white, malleable, and brilliant, metal. 262. *Chloride of magnesium* exists in sea-water. 263, 264. *Arseniate* and *phosphate of magnesia and ammonia* correspond in all respects. Levol proposes the former as a means of estimating arsenic. (V. Ann. de Chim. et de Phys. Aug. 1846.) 265. *Sulphate of manganese* is a rose-colored salt. 266, 267. *Chlorides of manganese*, of these there are two, ($MnCl$) and ($Mn^{2}Cl^{3}$.). 268. *Mannite* exists in celery and many sea-weeds. 269. *Margarine* exists in solid fat. 270, 271. *Mellon* and *melamine*, the products of the distillation of sulphocyanate of ammonia. 272. *Mercaptan* or *sulphur alcohol*, is a colorless, volatile fluid. 273. *Sulphate of mercury* is an insoluble, white, subcrystalline powder. 274. *Metacetone* is an oily liquid. 275. *Metaldehyde* exists in aldehyde. 276. *Methal*, or *methylic alcohol*, is the *pyroxylic spirit* of commerce. 277. *Mether*, or *methylic ether*, is also called *wood ether*. 278. *Molybdenum*, a rare metal. 279. *Murexide* exists in uric acid. 280. *Maleic acid* is formed from malic acid. 281. *Manganic acid* is an oxide of manganese. 282. *Meconic acid*, found in opium. 283. *Metacetonic acid* is a volatile liquid. 284. *Molybdenic acid*, an oxide of molybdenum. 285. *Mucic acid*, obtained from gum and milk sugar. 286. 287. *Myristic acid* and *myristine*, are contained in the nutmeg. 288. *Myricine*, contained in bees-wax.

289. *Naphtha* is yielded by petroleum by distillation. 290. *Naphthaline* exists in coal-tar. 291. *Narcotine*, an alkaloid found in

opium. 292. *Narceine* is a base contained in opium. 293. *Nickel* is a white, malleable metal; density, 8·27; melts at 3000°. 294. *Nicetine* is found in tobacco. 295. *Nitrobenzene* is a dense oily fluid. 296. *Nordhausen acid* is diluted sulphuric acid. 297. *Nitrobenzoic acid* is obtained from benzoilol. 298, 299. *Narcotina* and *Narcogenina*, are composed of C, H, N, and O.

300. *Oil of mustard* is $C^8H^5NS^2$. 301. *Oil of roses* is a carburet of hydrogen. 302. *Oil of cumin* has the formula $C^{20}H^{12}O^2$. 303. *Oil of dippel* is obtained from animal substances. 304. *Oleine* composes chiefly the fluid portion of animal fats. 305. *Osmium* is a rare metal. 306. *Ozone*, a volatile, odorous body given off during the electrolysis of water. 307. *Oleic acid*, obtained from fat. 308. *Opianic acid* is found in opium. 309, 310, 311, 312. *Osmic*, *Oxalovinic*, *Oxaluric*, and *Oxamic*, *acids*, are little used.

313. *Palladium*, a metal found with platinum. 314. *Phenol* is formed from salicylol. 315. *Phosgene gas*, is carbonic oxyd united to chlorine. 316, 317, 318, 319. *Acetate*, *Chromate*, *Cyanate*, and *Sulphate*, *of Potassa*, are little used. 320. *Chlorate of potassa* detonates with combustible bodies. 321. *Prussiate of potassa* is used in the preparation of Prussian blue. 322. *Proteine* is allied to albumen and fibrine. 323, 324, 325, 326, 327, 328, 329, 330, 331, 332. *Parabanic*, *Paratartric*, *Pectic*, *Pelargonic*, *Permanganic*, *Phosphoric*, *Picric*, *Pimelic*, *Phosphovinic*, and *Platinocyanic*, *acids*, are little used. 333. *Pyroligneous acid* is used in the arts of dyeing and calico-printing. 334, 335. *Pelopium* and *Niobium* are rare metals.

336. *Quinoline* is an alkaloid.

337. *Rhodium* is a rare metal. 338. *Ruthenium* is a rare metal.

339, 340. *Salicylic acid* is formed from *salicylol*, which is obtained from the spirea ulmaria. 341. *Silicon* is a non-metallic element. 342, 343. *Acetate* and *Cyanide of Silver* are little used, as also the (344, 345, 346, 347,) *Acetate*, *Nitrate*, *Phosphate*, and *Silicate*, *of Soda*. 348. *Strontium*, a rare metal.

349. *Tellurium*, a rare non-metallic element. 350, 351, 352. *Thorium* is a rare metal, as also *Titonium*, and *Tungsten*. 353, 354, 355, 356, 357. *Tannic*, *Tartarovinic*, *Telluric*, *Titanic* and *Tungstic*, *acids*, are little used.

358. *Urea* abounds in urine. 359, 360. *Ulmic* and *Uric acids* are from organic substances.

361. *Vanadium* is a rare metal.

362. *Xyloidine* is formed by the action of nitric acid on vegetable substances. 363. *Yttrium* is a metal little known.

364, 365. *Acetate* and *Lactate of Zinc*, are little used. 366. *Zirconium* is a rare metal, found in the earth zircon.

FLUORINE.—Louyet finds that it presents stronger analogies with oxygen and sulphur, than with chlorine, bromine, iodine, and the allied bodies. Equiv. 239·81.

Galvanism.—A patent has been granted for a process of purifying liquids by galvanism. Ice has recently been found to be a conductor. An improvement has been made on Grove's Battery, in which, by the use of sulphate of soda, the action is more uniform, and the mercury unattacked. Goodman has constructed a new and practical form of voltaic battery of the highest powers, in which potassium forms the positive element.—(V. Phil. Mag., Feb., 1847; Royal Soc., Jan. 11, 1847.)

Heat.—The subjoined temperature at which some of the most remarkable effects of heat are produced, are, excepting the first, thus given by Kane:

—	175°.F.	The greatest cold that has been produced.
—	121°.	The solid compound of alcohol and carbonic acid melts.
—	91°.	Greatest cold by ordinary freezing mixtures.
—	58°.	Temperature of the planetary spaces.
—	60°.	Greatest cold observed in the arctic regions.
—	47°.	Sulphuric ether congeals.
—	45°.	Nitric acid congeals.
—	39°.	Mercury congeals.
+	1°.	Oil of vitriol freezes.
+	14°.	Oil of turpentine freezes.
+	20°.	Wine freezes.
+	25°.	Blood freezes.
+	32°.	Ice melts.
+	36°.	Olive oil freezes.
+	98°.	Heat of human blood.
+	108°.	Phosphorous melts.
+	174°.	Alcohol boils.
+	201°.	Rose's metal melts.
+	212°.	Water boils.
+	218°.	Sulphur melts.
+	662°.	Mercury boils.
+	810°.	Antimony melts.
+	980°.	Red heat.
+	1141°.	Heat of a common fire.
+	1869°.	Brass melts.
+	1873°.	Silver melts.
	1996°.	Copper melts.
	2200°.	Gold melts.
	2786°.	Cast iron melts.

The most delicate measure of heat that has been contrived, is the *Thermo-multiplier* of Melloni, founded on the measurement of a thermo-electric current. It is so delicate, that the radiant heat of the hand held near the thermo-electric pile, causes the needle of the galvanometer to move some 10°.

Hydro-Oxygen Blowpipe.—Dr. Hare has made improvements in its construction and supply, by which rhodium, iridium, or the osmiuret of iridium, also platinum in the large way, have been fused.—(V. Am. Jour. Sci. & Arts, July, 1847.)

Light.—Dr. Draper fixes the temperature at which bodies become self-luminous at 977°; and shows that as the temperature of an incandescent body rises, it emits rays of light of an increasing refrangibility.—(V. Am. Jour. Sci. & Arts, Nov., 1847.) The same philosopher proves that the flames of various vapors and gases yield all the colors of the spectrum; that flames consist of a series of concentric and differently colored shells; explains the nature of colored flames, shewing, *e. g.*, why carbonic oxyd burns blue, and cyanogen gas red; shews that the introduction of air into the interior of a flame produces the distinction of the red and orange strata, and converts them into violet; and determines the physical cause of the production of light by chemical action.—(V. Am. Jour. Sci. & Arts., March, 1848.) Herschel has discovered rays beyond the limits of the violet, and calls their color, *lavender.* Consequently there are 8 prismatic colors. Brucke has shown that brown is nothing more than the complementary color to that of Herschel's lavender gray rays, *i. e.*, white light from which those have been removed.—(V. *ib.*, Jan., 1849.)

Magnetism.—To produce permanent magnets, having the greatest fixity and capacity conjointly secured, the general properties which the steel should possess, according to Petrie, should be as follows:

In a soft state.	*In a hard state.*
General appearance, uniform darkish grey.	Uniform white.
Rather a large grain, compared with razor steel, (or finer if much rolled.)	A smaller grain than it was before.
Rather irregular in size and shape of grain, unless fine, rounded crystallization.	Rather more regular than before.—*Rounded* crystallization disappears. Grains individually distinct, with good metallic lustre.
Close texture, without cavities.	Not particularly close.
Rather tough for steel.	Brittle, and very hard.
Attracted considerably before magnetizing.	Ditto.
Loses induced magnetism more freely than other steels.	Retains magnetism well and abundantly.

The iron should be the purest soft iron, *charcoal made;* the Swedish, from the Dunnamore mine, is the best; and in the process of hardening, it should be heated in melted lead. (V. Am. Jour. Sci. and Arts, Jan., 1847.) Dr. Scoresby has discovered a new and superior mode of developing the magnetic condition in steel bars, by interposing a thin plate of soft iron between the operating magnet and the bar of steel to be magnetized. (V. *ibid.*)

Minerals.—Hausemann considers the irised colors on minerals, like that on steel, due to a film covering the surface. (Am. Jour Sci. & Arts, Sept., 1848.)

Phosphorescence—is by some considered an imponderable agent

PHOSPHORUS.—Schrotter has ascertained that the red substance formed on the surface of phosphorous exposed to the light, is simply an isomeric transformation of phosphorous. (V. Am. Jour. Sci. & Arts, Jan., 1849.)

PHOTOGRAPHY—the art or practice of forming permanent images by means of chemical changes produced by light. Process: A plate of silvered copper, carefully cleaned, is iodized to a pale lemon color, then brominized to a golden yellow, and exposed to the focal image of the object in a camera obscura. Mercurial vapor is then allowed to play upon the proof; and farther influence of light removed by washing the plate in a solution of hyposulphite of soda. It is afterward gilded by pouring over the silver surface a weak solution of the chloride of gold in hyposulphite of potash.

POLARIZATION.—We are indebted to Faraday for the discovery of the excitement of a molecular change in certain forms of glass, water, alcohol, oil, and other substances when under the influence of the magnetic and electric forces, sufficient to cause the rotation of a polarized ray. (V. Bird's Elements of Nat. Philos.; Am. Jour. Sci. & Arts, July, 1848.)

RADIATION.—Masson and Courtépée conclude, that, 1. The metals have much greater radiating power when in grains than when melted or in mass. 2. That the radiating power of a substance depends on the cohesion of its parts. 3. That if all bodies were reduced to the same degree of chemical subdivision, they would have at 180° F., the same radiating power. (V. Comp. Rend. Dec. 20, 1847.)

SAFETY LAMP.—Rev. W. Thorp has produced an improvement which will remedy all the defects of Davy's; affording five times more light, and being safe in every condition of the coal mine. (V. Jour. Frank. Institute, July, 1848.)

SPHEROIDAL STATE.—Faraday has congealed mercury in three seconds, by virtue of the spheroidal state, in an incandescent crucible. Beauvegard has constructed a steam-engine to be moved by the vapor of water in the spheroidal state, the elastic force of which is very great.

SYMBOLS.—An equivalent of oxygen is often expressed by a dot, two by two dots; *e. g.* $\dddot{S}$ signifies SO^3. A short line under a symbol signifies two equivalents of the base, *e. g.* $\underline{\ddot{Al}}$; sometimes it is denoted by a black letter, thus, $\ddot{\mathbf{Al}}$, in place of the line beneath.

WATER.—Its maximum density, according to Joule and Playfair, is 39°·1 F.; Despretz says 39°·176; Hallstrom, 39°·38; Hope, 39°·5; Deluc, 41°; Blagden and Gilpin, 39°; Lefebvre Gineau, 40°; Dalton, 38°; Muncke, 38°·804; Rumford, 38°·8; Stampfer, 38°·75 F. Mean = 39°·24.

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EXERCISES

FOR REVIEW AND EXAMINATION.

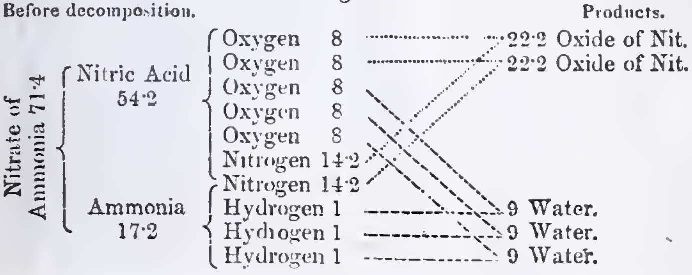
NOTE.

The engravings which have been used to illustrate this work are again introduced, in the order of the places in which they have appeared in the text. The reasons for this arrangement are the following: First, if it is not convenient or advisable that the pupils should draw all the figures upon the black board, they may be questioned upon them with their books opened at these pages. Their answers will evidently test their knowledge of the subject. Second, after having gone a certain distance in the work, it is necessary to review, in order that the subject which has been studied in parts may be considered as a whole. In aid of this process, which systematises the knowledge, and enlarges the scope and capacity of the mind, the figures as here repeated, will act as suggestive points, and bring before the memory all that branch of the subject with which each of them is connected.

PART I.

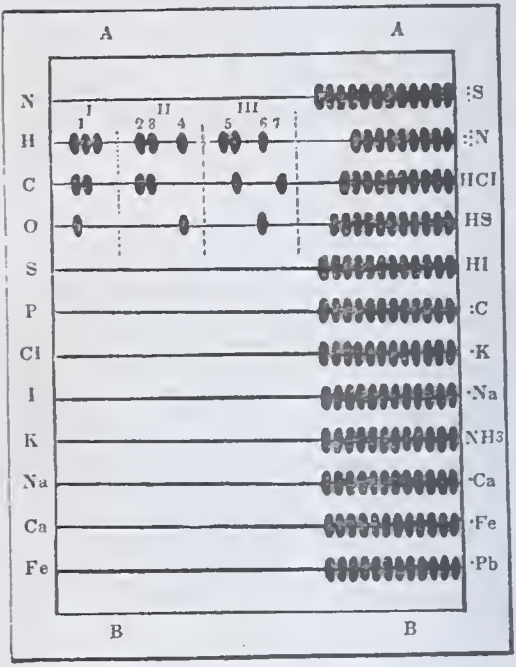
DECOMPOSITION OF NITRATE OF AMMONIA.

Fig. 1.



Symb. : $\vdots N + NH^{3} = 2{\cdot}N \& 3{\cdot}H.$

Fig. 2.



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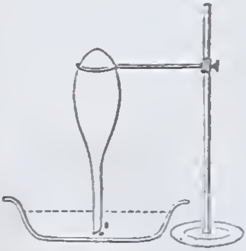

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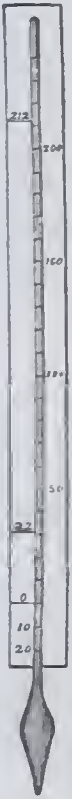

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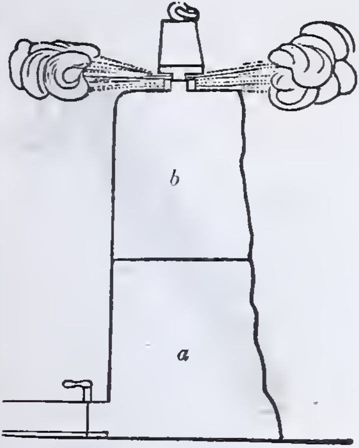

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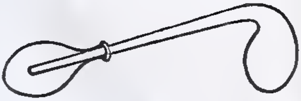

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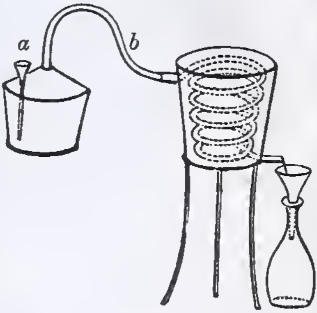

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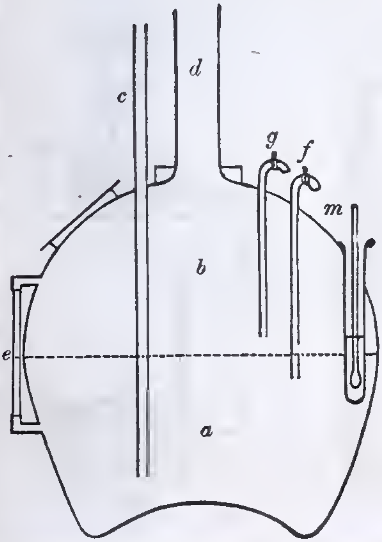

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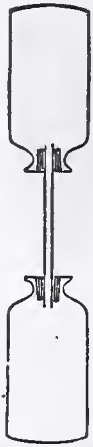

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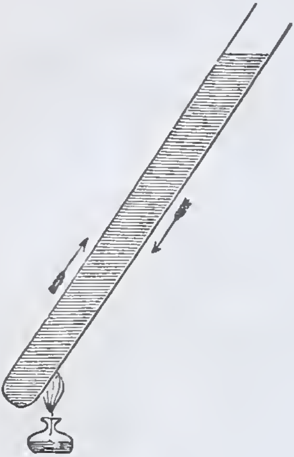

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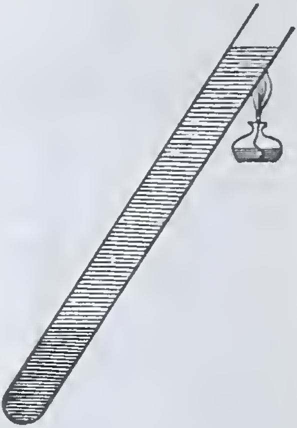

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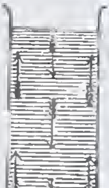

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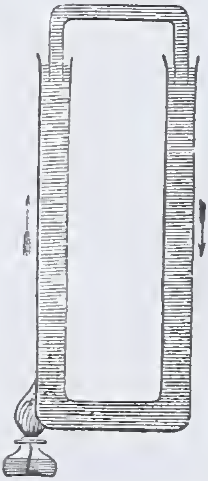

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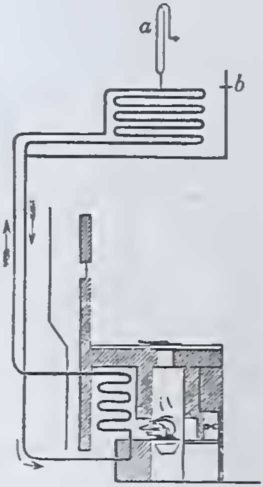

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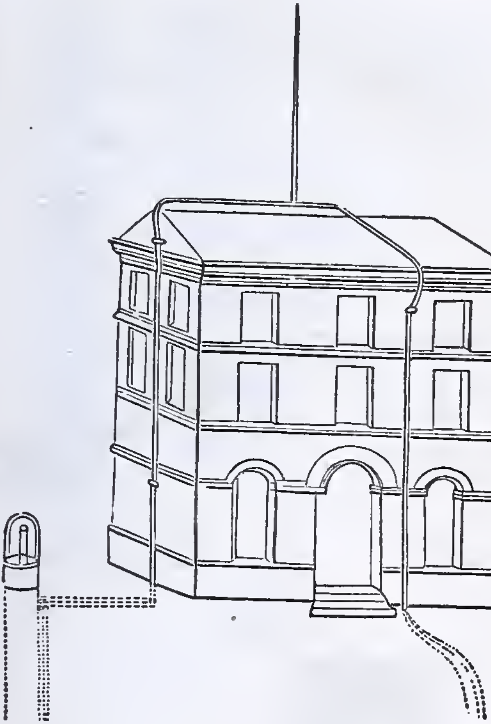

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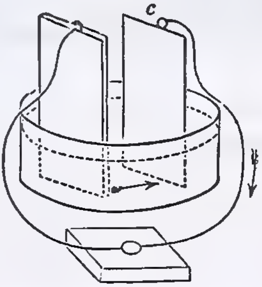

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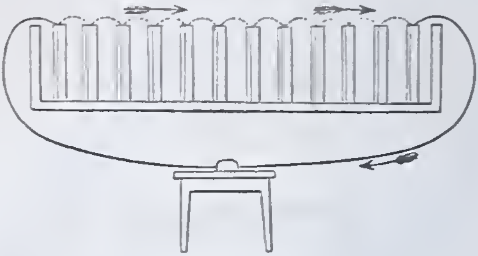

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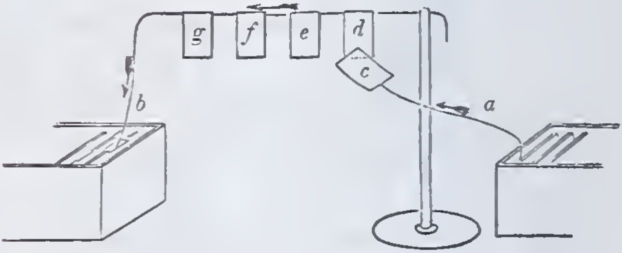

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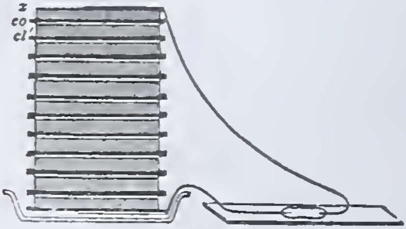

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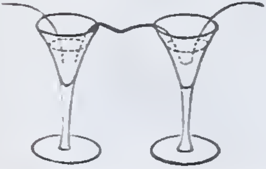
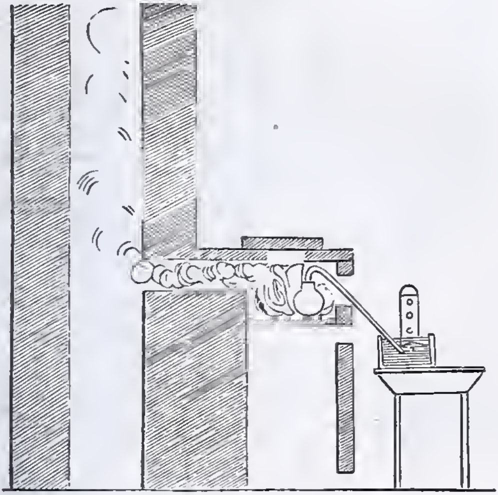


Fig. 21.

Fig. 22.



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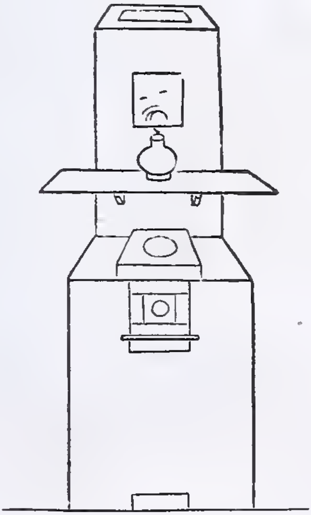

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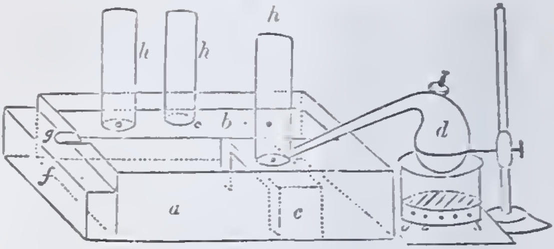

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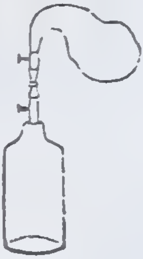

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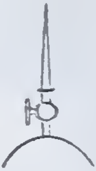

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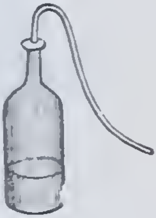

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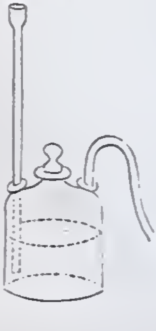

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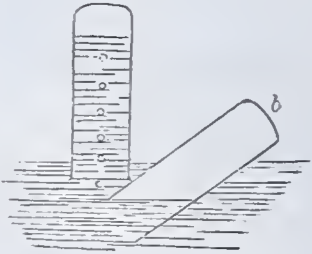

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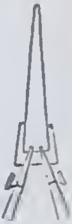

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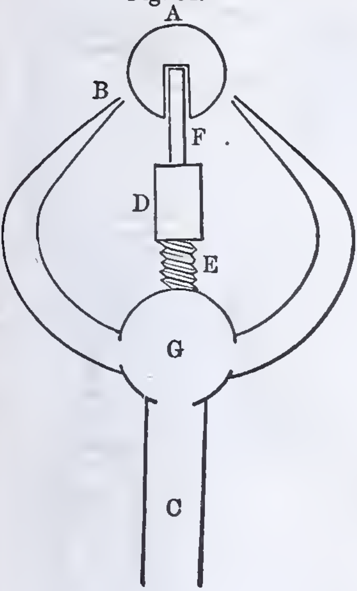

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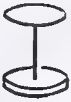

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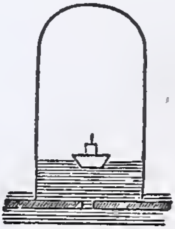

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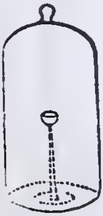

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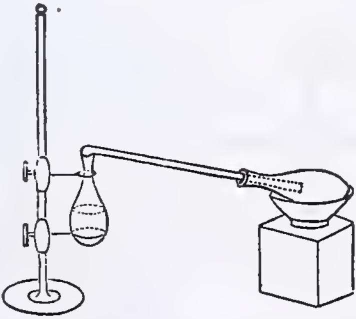

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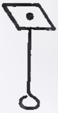

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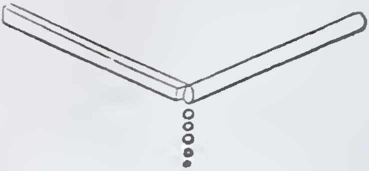

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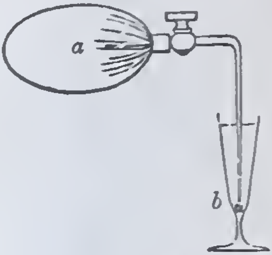

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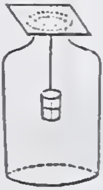

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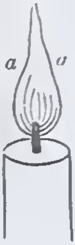

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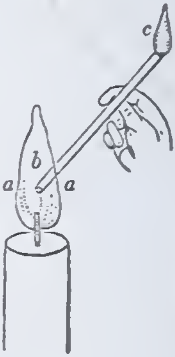

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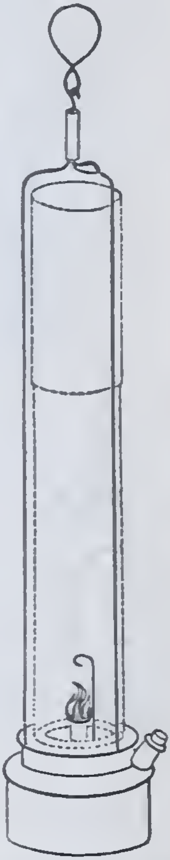

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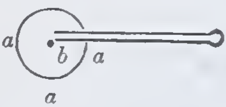

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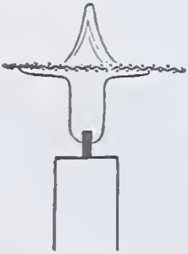

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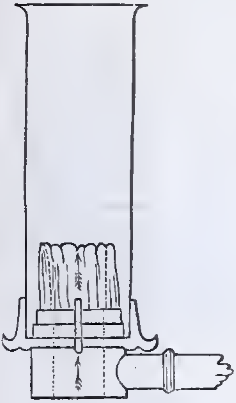

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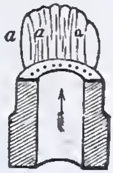

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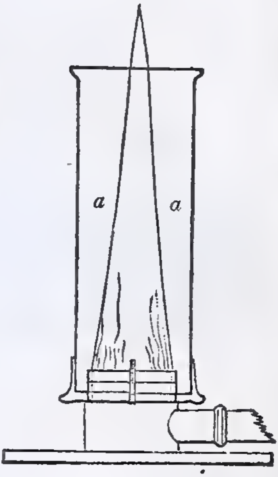

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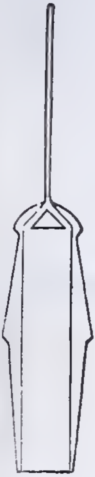

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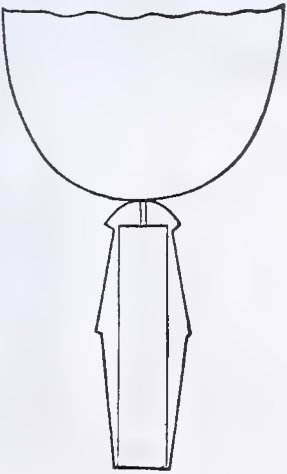

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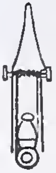

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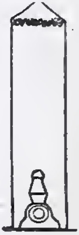

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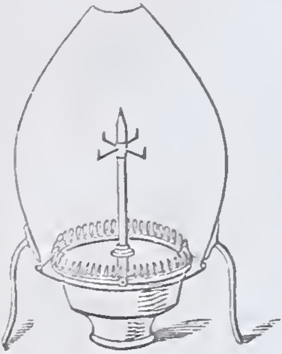

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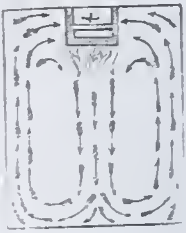

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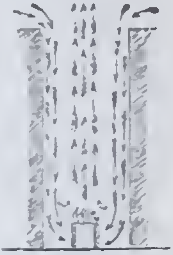

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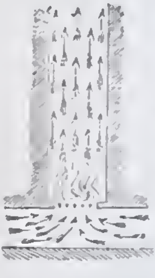

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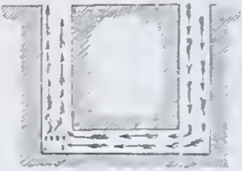

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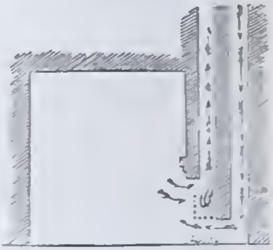

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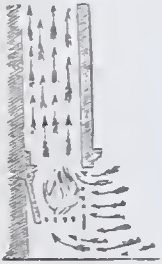

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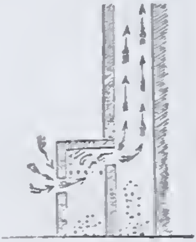

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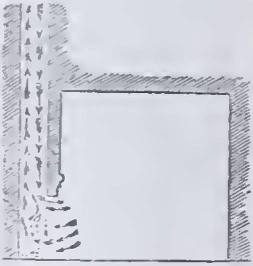

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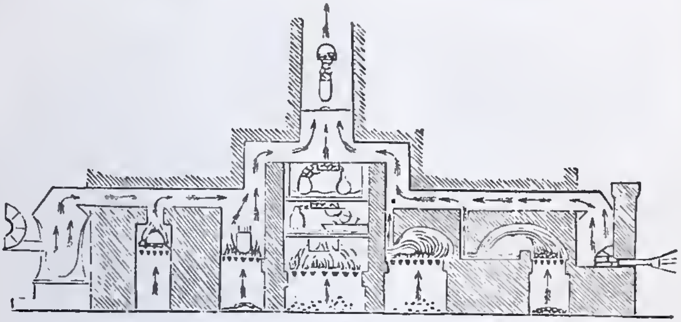

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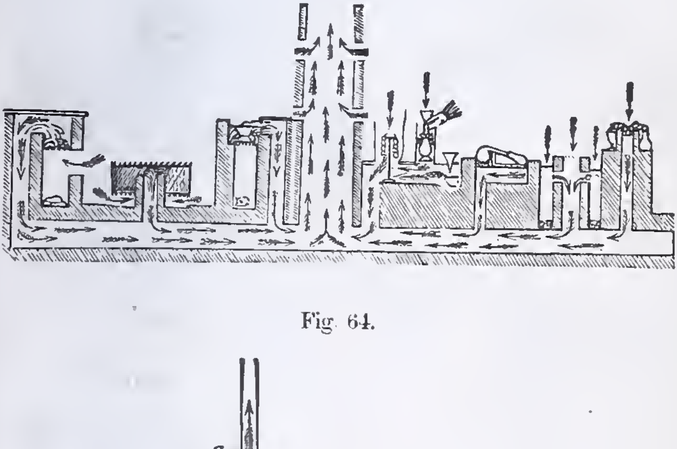

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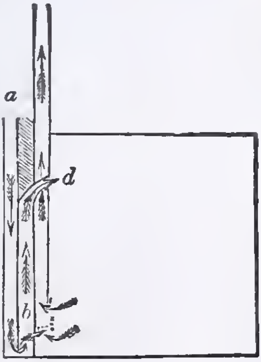

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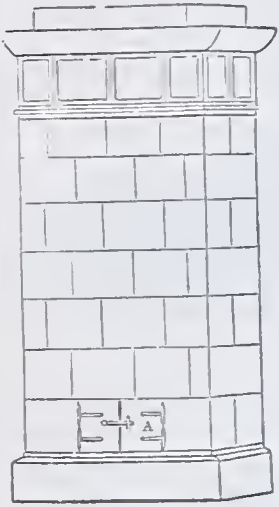

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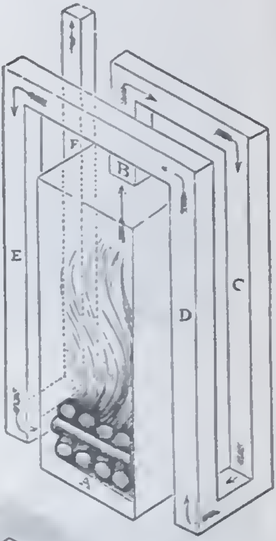

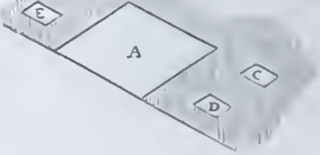

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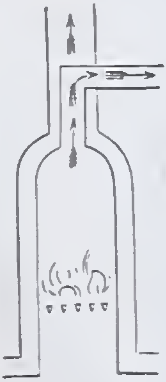

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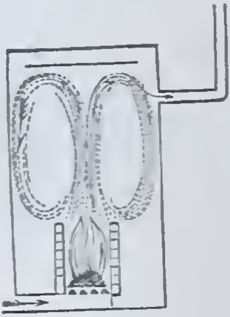

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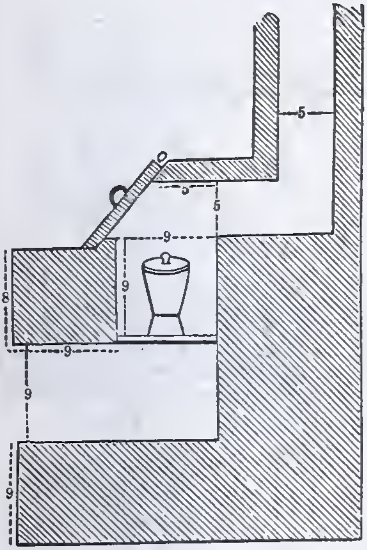

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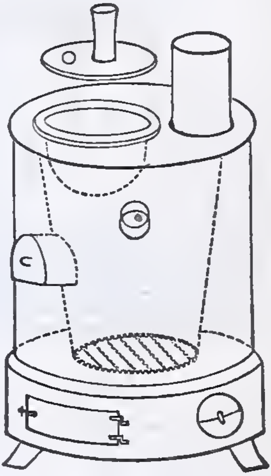

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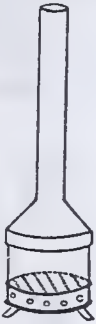

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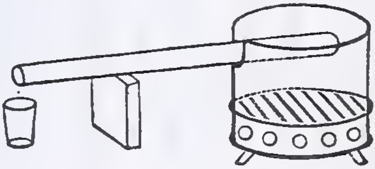

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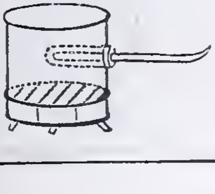

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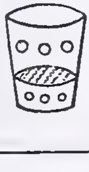

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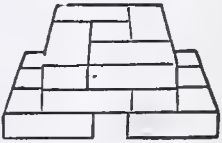

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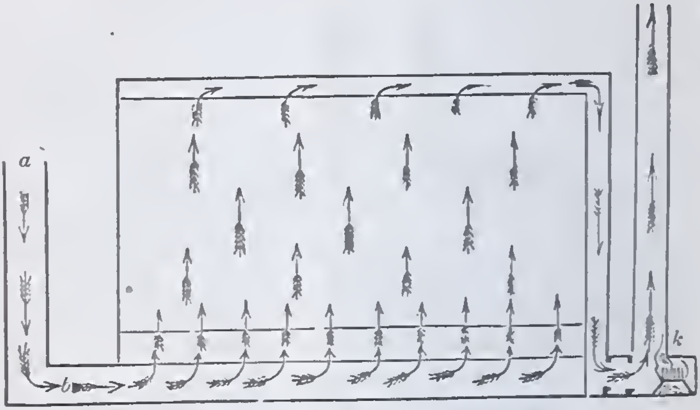

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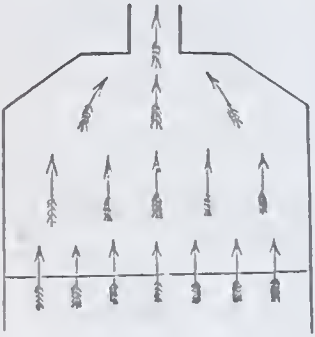

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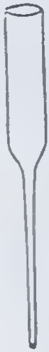

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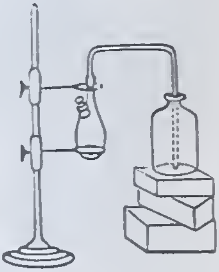

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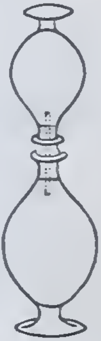

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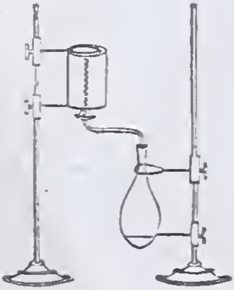

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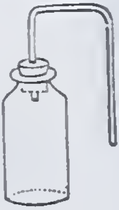

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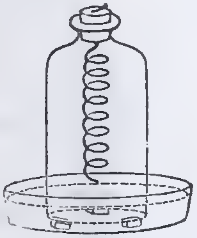

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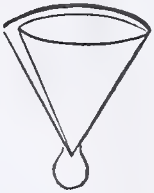

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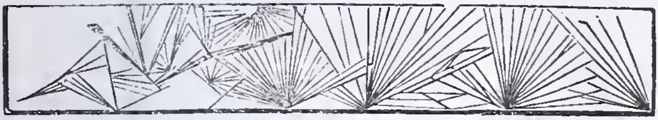

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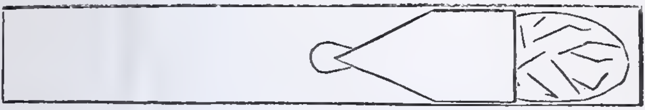

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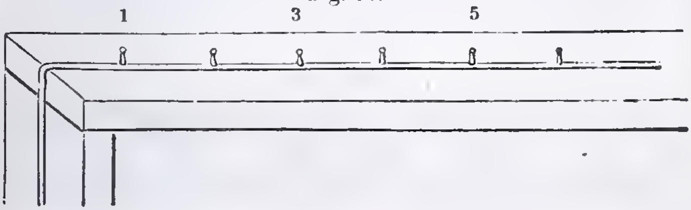
Fig. 89.

Fig. 90.



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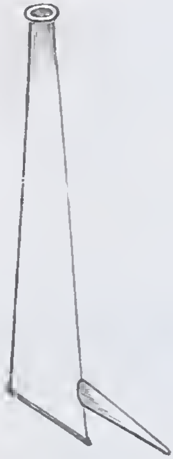

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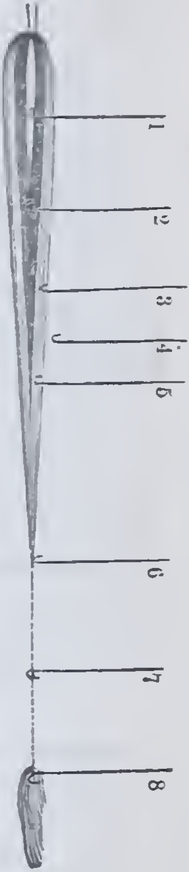

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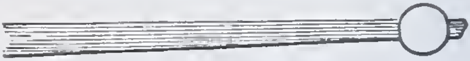

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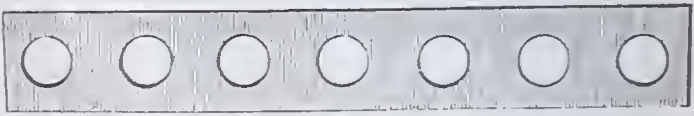

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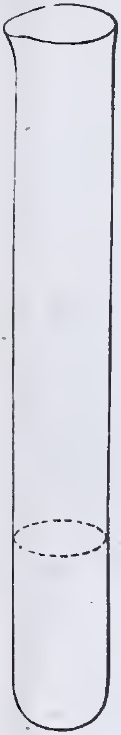

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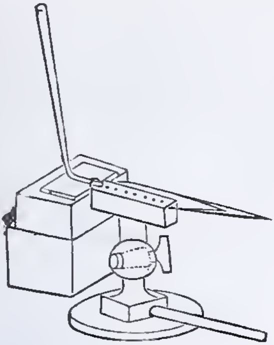

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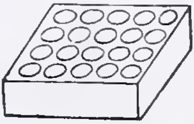

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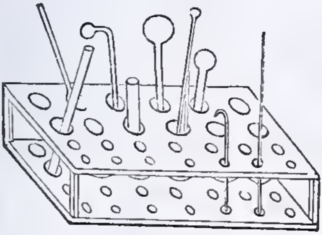

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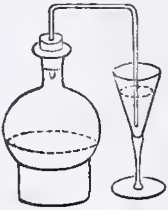

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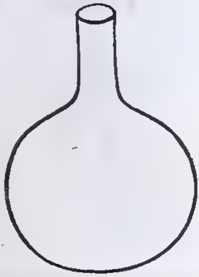

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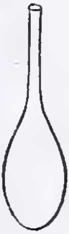

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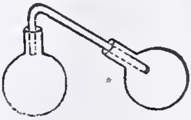

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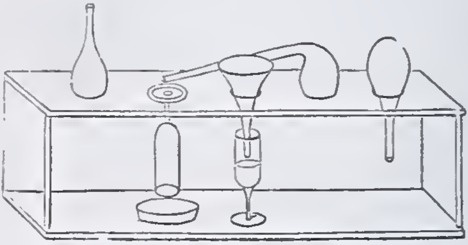

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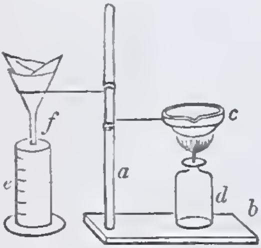

Fig. 106.

Fig. 107.

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Fig. 109.

Fig. 110.

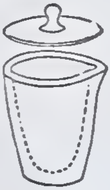
Fig. 111.

Fig. 112.

Fig. 113.

Fig. 114

Fig. 115.



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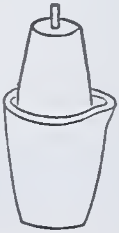

Fig. 117.

PART II.

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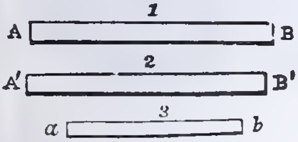

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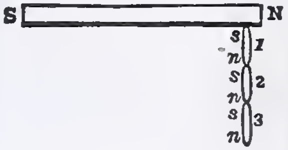

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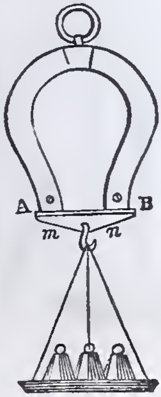

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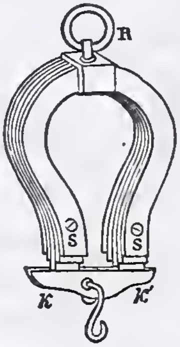

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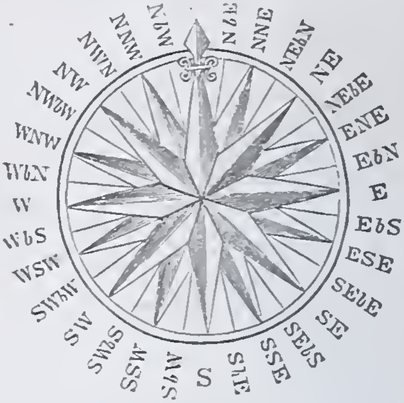

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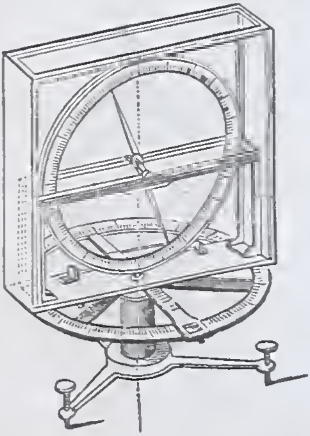

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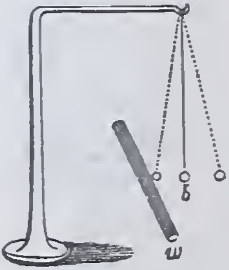

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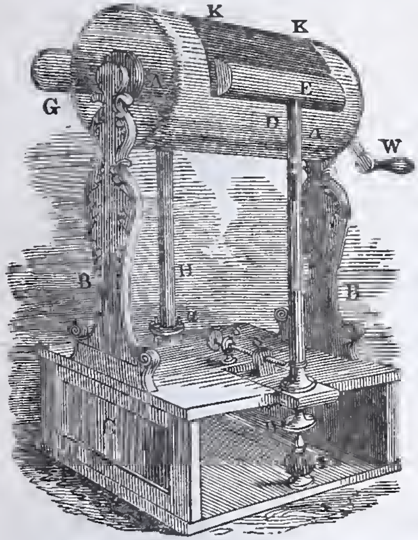

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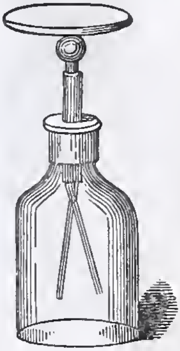

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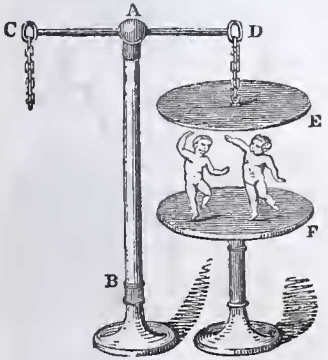

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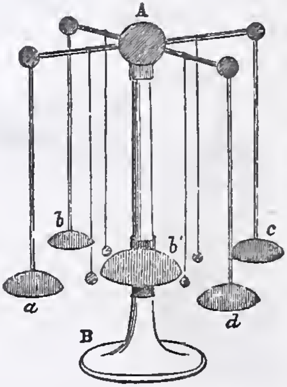

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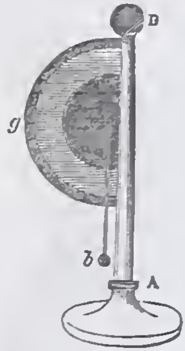

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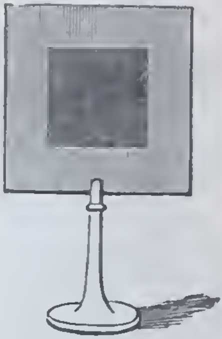

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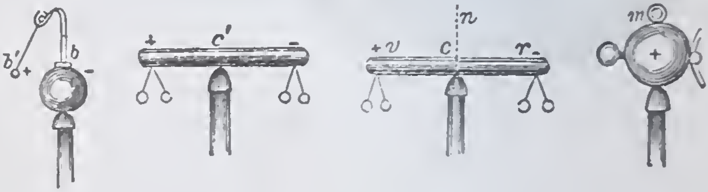

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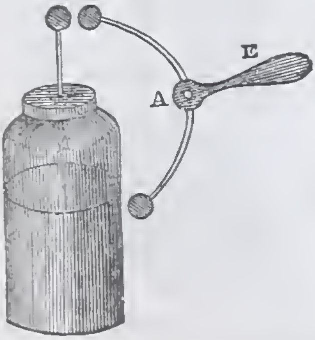

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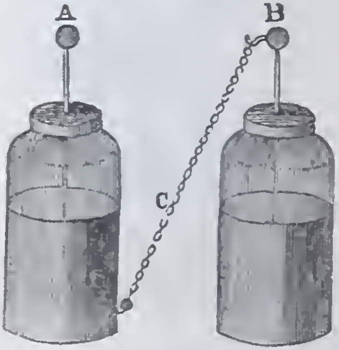

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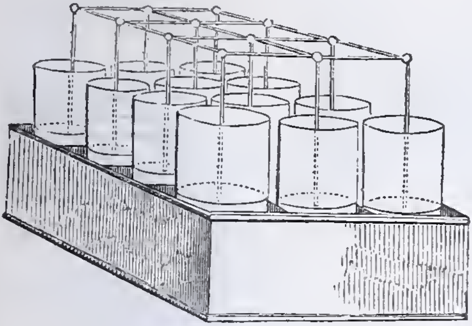

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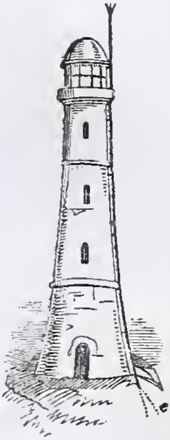

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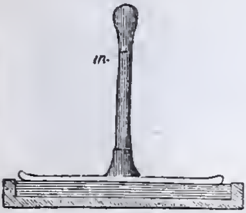

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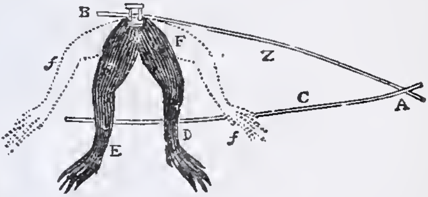

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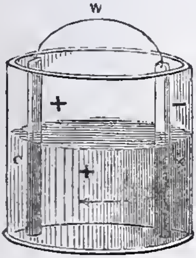

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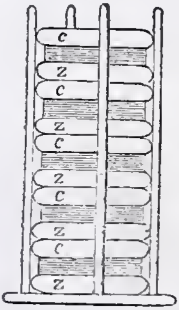

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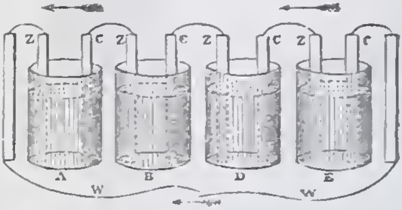

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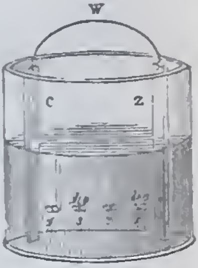

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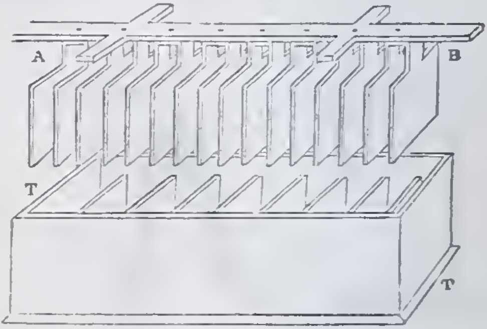

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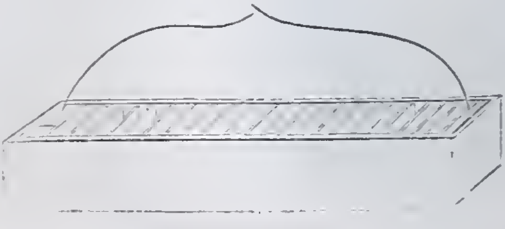

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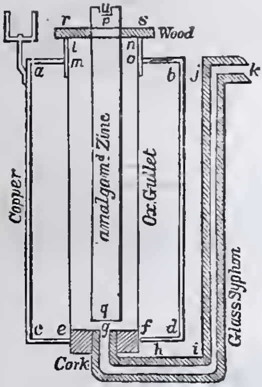

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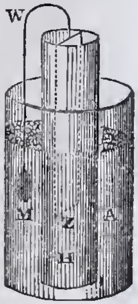

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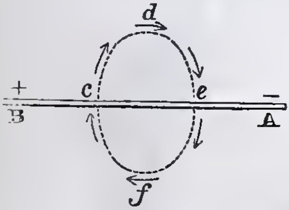

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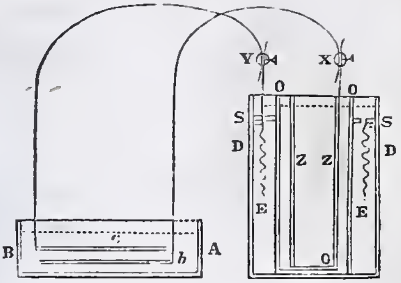

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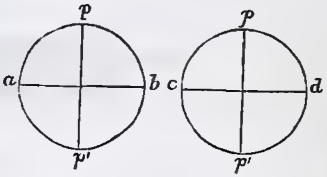

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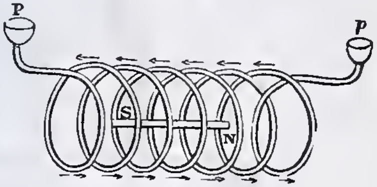

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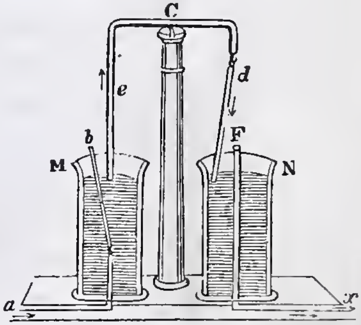

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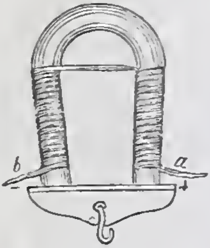

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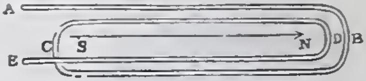

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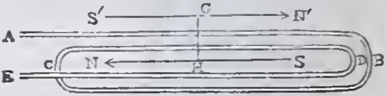

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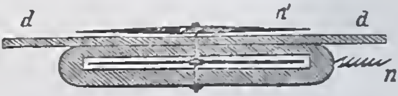

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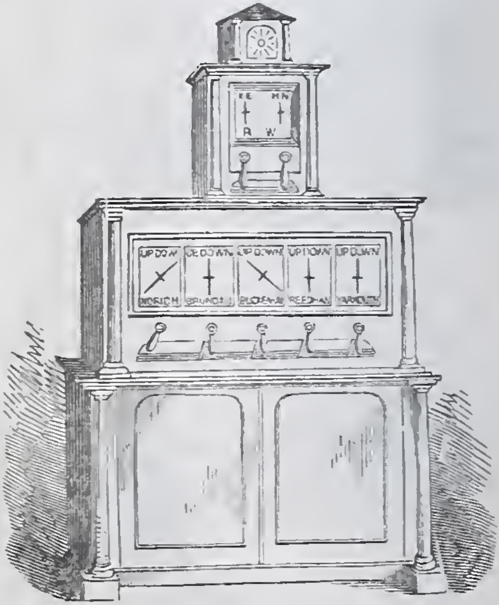

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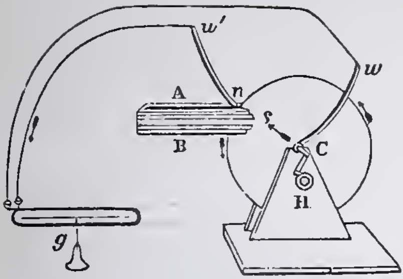

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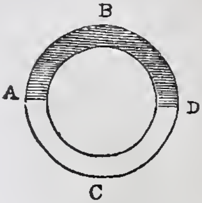

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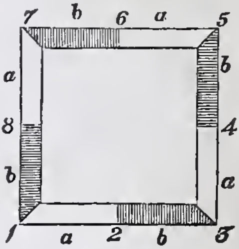

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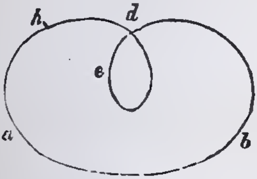

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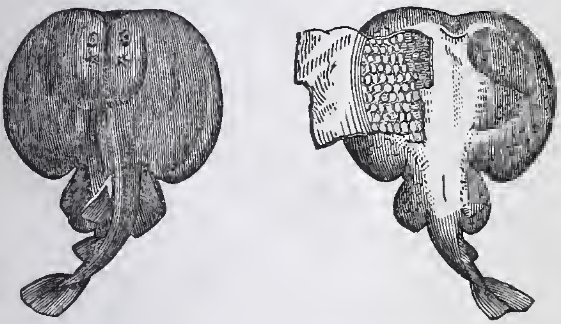

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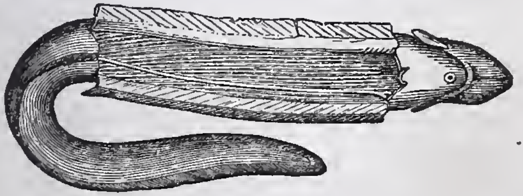

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